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Aeronautical Engineering REVIEW

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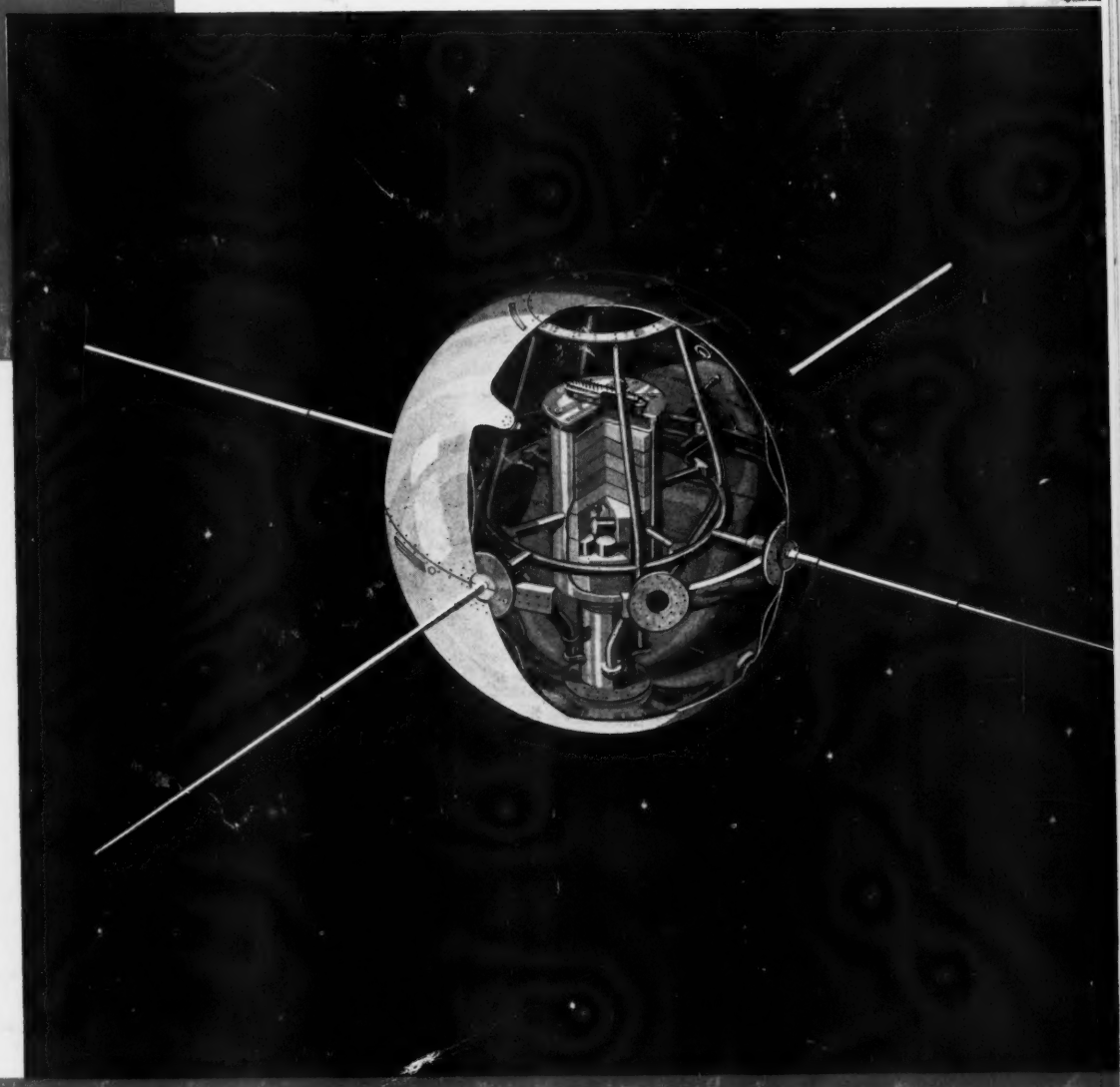

SEVENTH ANNUAL ISSUE

ELECTRONICS IN AVIATION

May, 1957

LIQUID COOLING of Electronic Tubes

WITH Eastern COOLING UNITS

By a sustained program of research, Eastern continuously extends the uses of the latest units in electronic tube cooling, pressurizing electronic equipment, and pumping fuels and hydraulic fluids. Research and testing laboratories, a model shop, and three manufacturing plants provide the specialized equipment and manpower to turn out fully qualified units to meet appropriate government specifications.

From our extensive line of existing units, adaptations of these units, or completely new designs, Eastern can provide equipment to handle your project well. Your inquiry is welcomed.

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Eastern Cooling Units provide coolant liquid for maintaining within safe operating temperature limits liquid cooled electronic tubes or similar devices. The units are completely self-contained and usually comprise such components as heat exchangers, fans or blowers, liquid pumps, reservoirs, flow switch, thermostat, etc.

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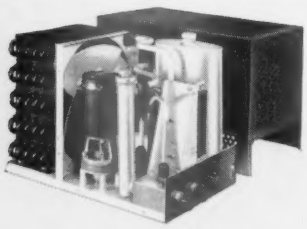
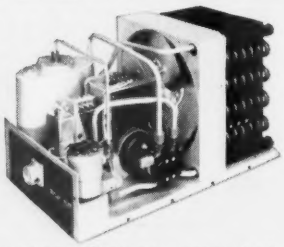
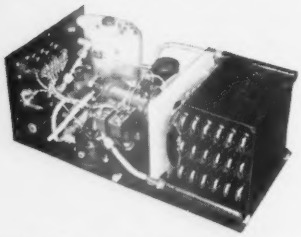
Eastern welcomes your consultation on liquid cooling problems ranging from 200 to 20,000 watts dissipation.



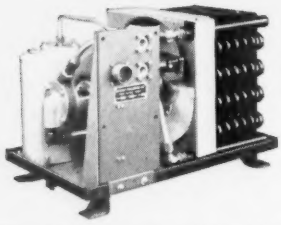
MODEL MB-175, TYPE 200 DISSIPATION: 2,000 watts. ALTITUDE RANGE: sea level to 50,000 feet. POWER REQUIRED: 28 volts D.C. WEIGHT: 25 pounds. SIZE: 10" x 15-15/16" x 10¾" high.



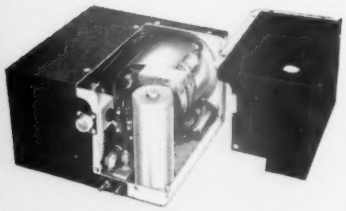
MODEL E/HT-205, TYPE 200A DISSIPATION: 1600 watts. ALTITUDE RANGE: sea level to 5,000 feet. POWER REQUIRED: 28 volts D.C. WEIGHT: 25 pounds. SIZE: 10" x 21" x 10" high.



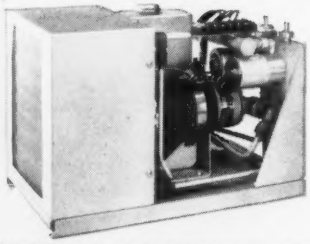
MODEL MB-177, TYPE 202 DISSIPATION: 1700 watts. ALTITUDE RANGE: sea level to 50,000 feet. POWER REQUIRED: 110 volt, 400 cycle, 3 phase. WEIGHT: 27 pounds. SIZE: 10" x 19 15/32" x 7⅛" high, per JAN-C-1720A, size B1-D1.



MODEL E/HT-210, TYPE 200 DISSIPATION: 1500 watts. ALTITUDE RANGE: sea level to 10,000 feet. POWER REQUIRED: 208 volts, 400 cycle, 3 phase. WEIGHT: 35 pounds. SIZE: 11¼" x 19½" x 12½" high.



MODEL E/HT-200, TYPE 201 DISSIPATION: 1,000 watts. ALTITUDE RANGE: sea level to 50,000 feet. POWER REQUIRED: 28 volts D.C. WEIGHT: 14½ pounds. SIZE: 10" x 10" x 6" high.



MODEL NO. 5-A DISSIPATION: 1,000 watts. ALTITUDE RANGE: sea level to 5,000 feet. POWER REQUIRED: 100 to 110 volts D.C. WEIGHT: 10 pounds. SIZE: 7⅞" x 13½" x 9-1/16" high.

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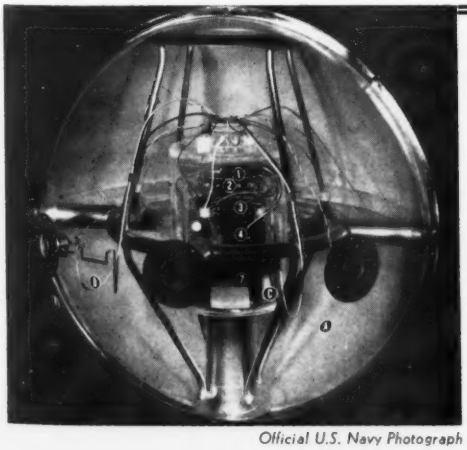

Official U.S. Navy Photograph

Cover—Instruments in the U.S. Naval Research Laboratory Earth Satellite will weigh about 10.75 lbs. Letters and numbers on this semitransparent model show those that will aid new study of the upper atmosphere. Letters A, B, C, and D locate a solar cell, ion chamber, thermistors-semi-conductor, and an erosion gauge, respectively. Numbers show: 1, minitrack transmitter; 2, meteor collision memory storage; 3, telemetry coding system; 4, Lyman alpha storage; 5, meteor collision amplifier; 6, Lyman alpha-current amplifier; 7, mercury batteries for power supply.

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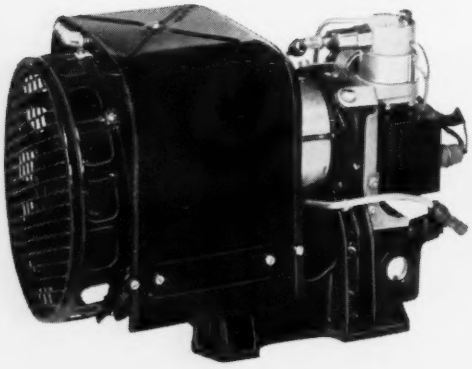
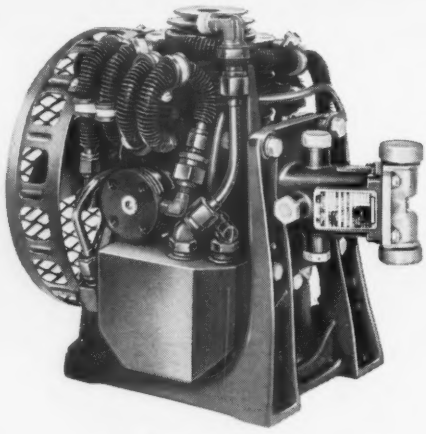
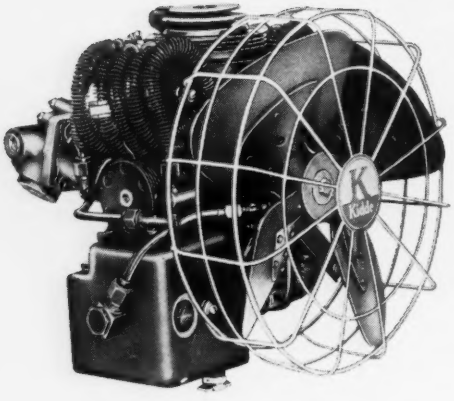


2 cfm Compressor Package



4 cfm Compressor



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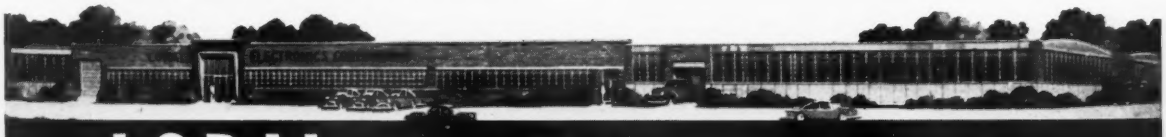

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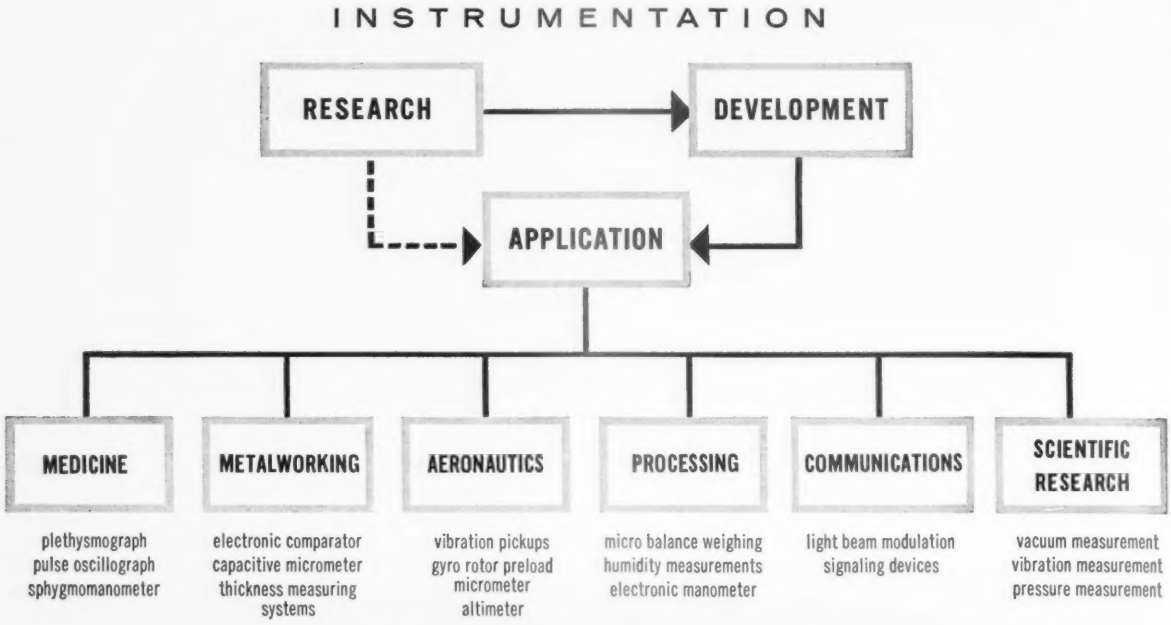

an idea is the solution to every problem

Decker Aviation is a company of ideas.

Not long ago, for example, Decker took the idea of an ionization transducer and brought the idea to reality . . . then used it imaginatively to solve pressing problems in any number of far flung fields.

In medicine, Decker applied the transducer to the improvement of such basic instruments as the plethysmograph . . . giving medical researchers a new magnitude of sensitivity in their explorations.

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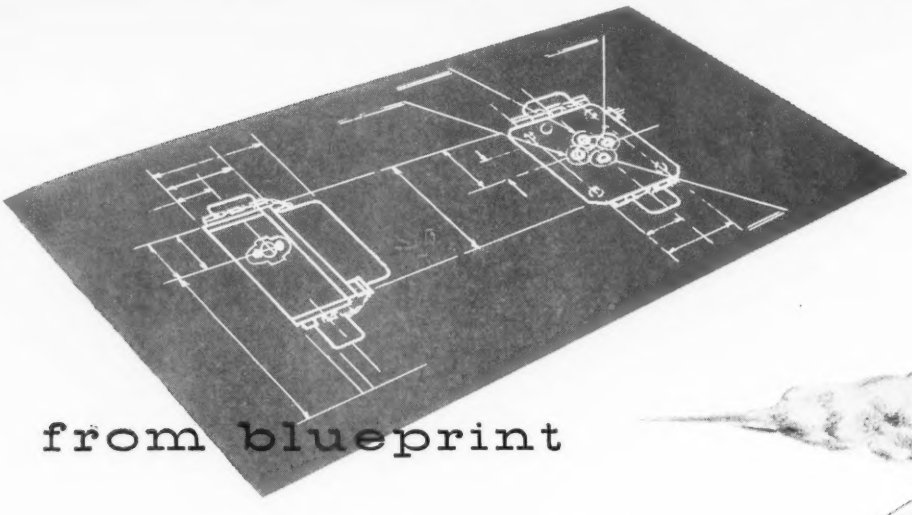
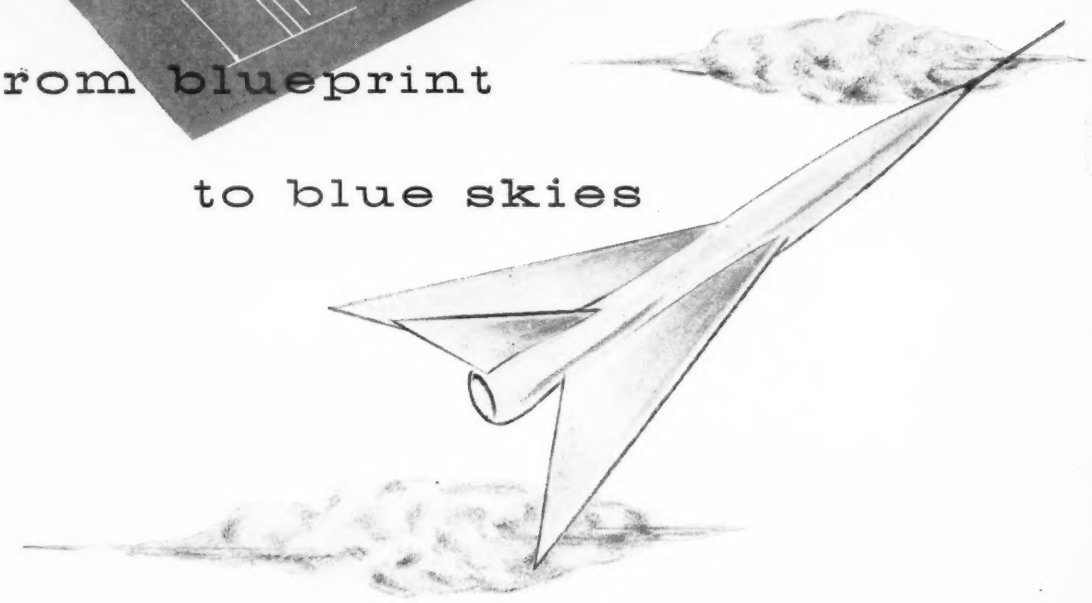


from blueprint

to blue skies



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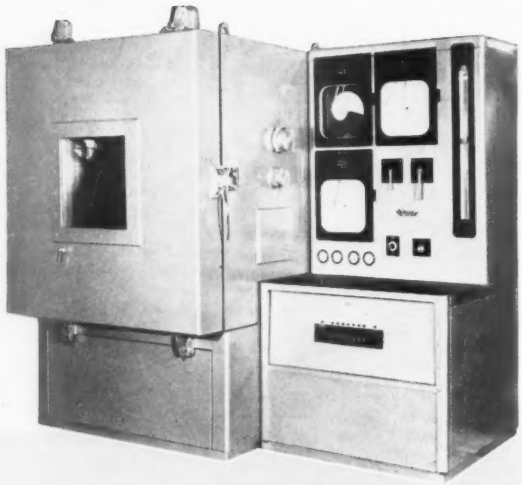

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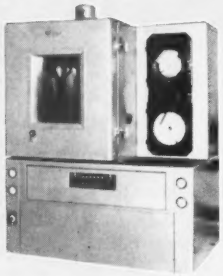

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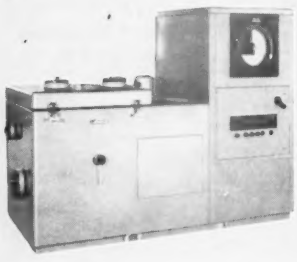

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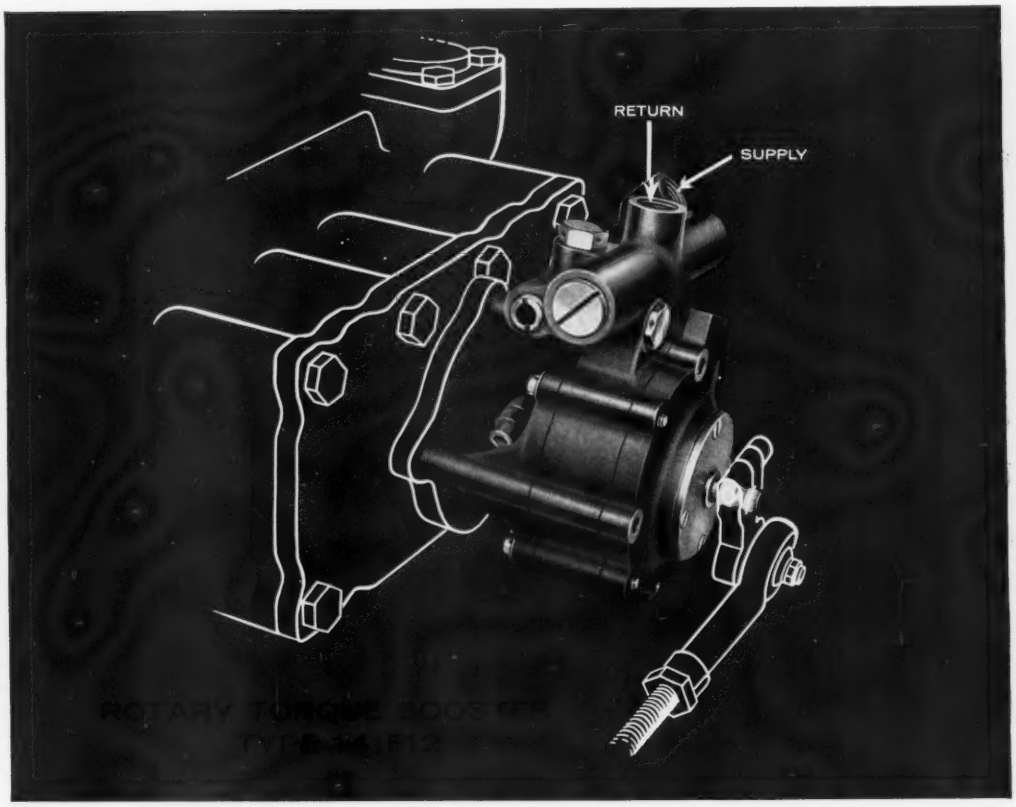

The Type 141F12 Rotary Torque Booster is a fail-safe hydraulic amplifier. It is commonly "sandwiched" between a turbojet engine control and the throttle lever — reduces substantially the pilot's effort to move the throttle. In a typical installation with a fuel supply of 200 psi, the torque output to the engine control is 80 inch-pounds at an input level of 10 inch-pounds. Either fuel or oil may be used as the operating medium. Pressures from 150 to 900 psig are suitable.

Unique dirt-insensitive servo valve construction, plus double failure protection against torque feedback to throttle input, accounts for the high reliability of the Booster. Even if hydraulic power should fail, a direct mechanical link permits no-boost operation of the engine control. Construction is such that input overloads of 600 inch-pounds can be handled without damage.

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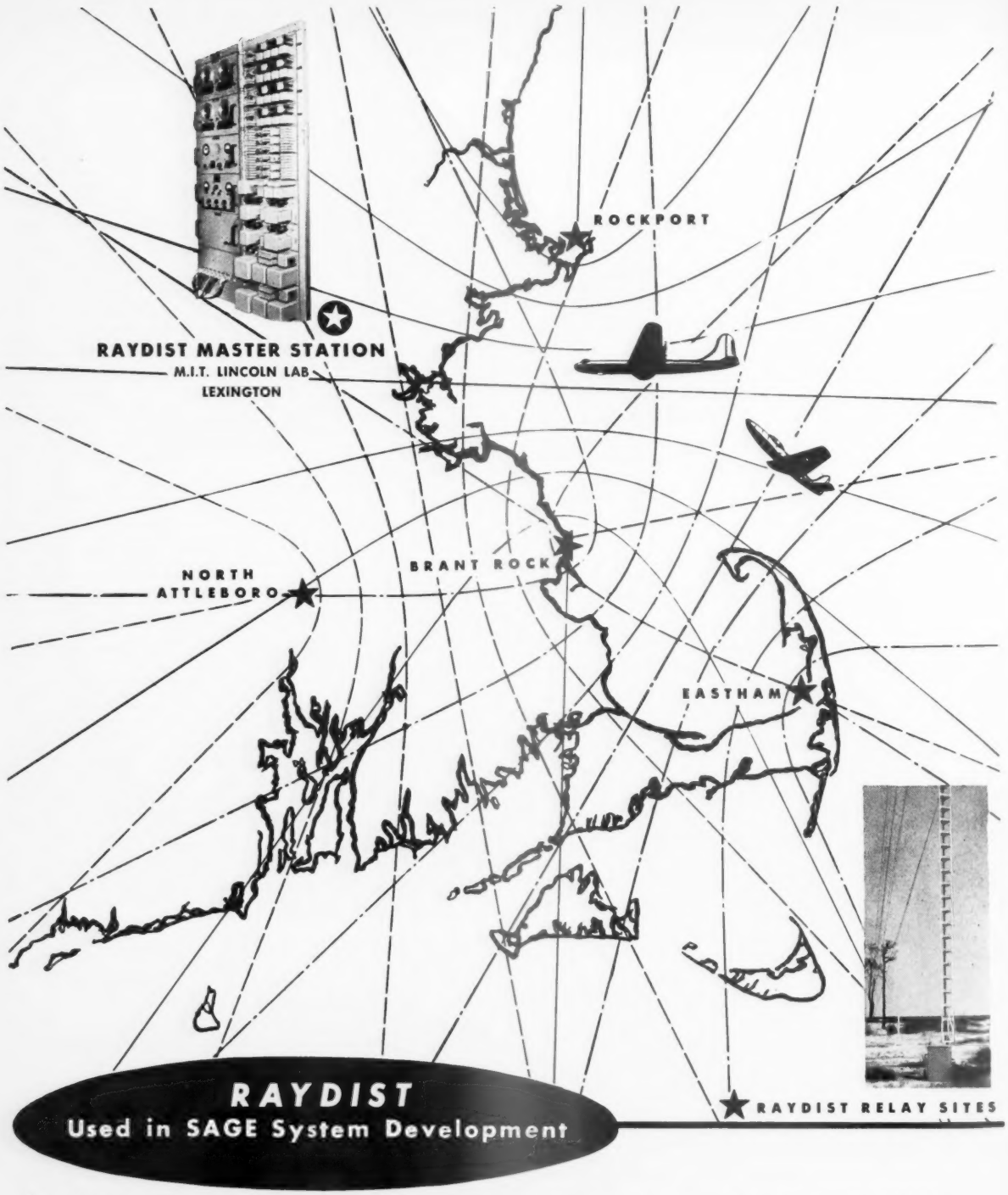

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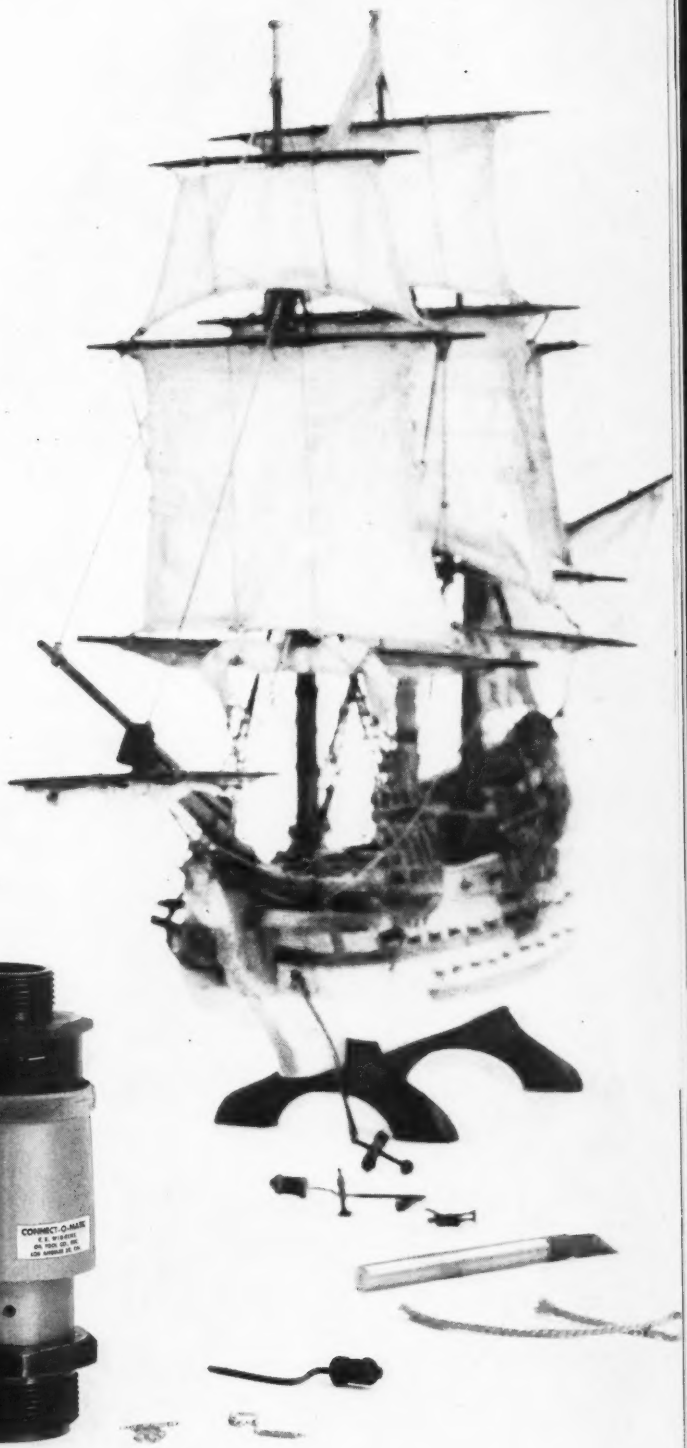

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some how
some place

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the stratosphere,
or outer space;

Whether you dream of the complex or the basic,
regardless of industry or application,
there is a Miracle Material called STAFOAM
that will open new vistas
and remove present limitations.

ready for reality

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A liquid...poured in place...foams and sets. The miracle material, STAFOAM, results. ...A material with any set of characteristics pre-determined by YOU. It can be formulated to produce a material as hard as steel. It can be formulated to produce a material of sponge-like flexibility. Or it can be formulated to any density between these extremes. STAFOAM can have pre-determined strength, texture, rigidity, porosity, thermal characteristics, insulation characteristics (heat, cold, electrical, shock and sound), and color.

STAFOAM is a polyurethane foam, formed by mixing isocyanates and resinous polymers in liquid form. In some formulas, STAFOAM is thermo-setting; in others, it is thermo-plastic. Consider what just one of STAFOAM'S valuable characteristics... foamed in place...can mean in savings to your manufacturing process...in engineering, in tooling, in assembly and of course in labor. STAFOAM is a material that could well revolutionize your manufacturing methods...or even your product.

The applications of STAFOAM are limited only by your imagination.

STAFOAM is in your future.

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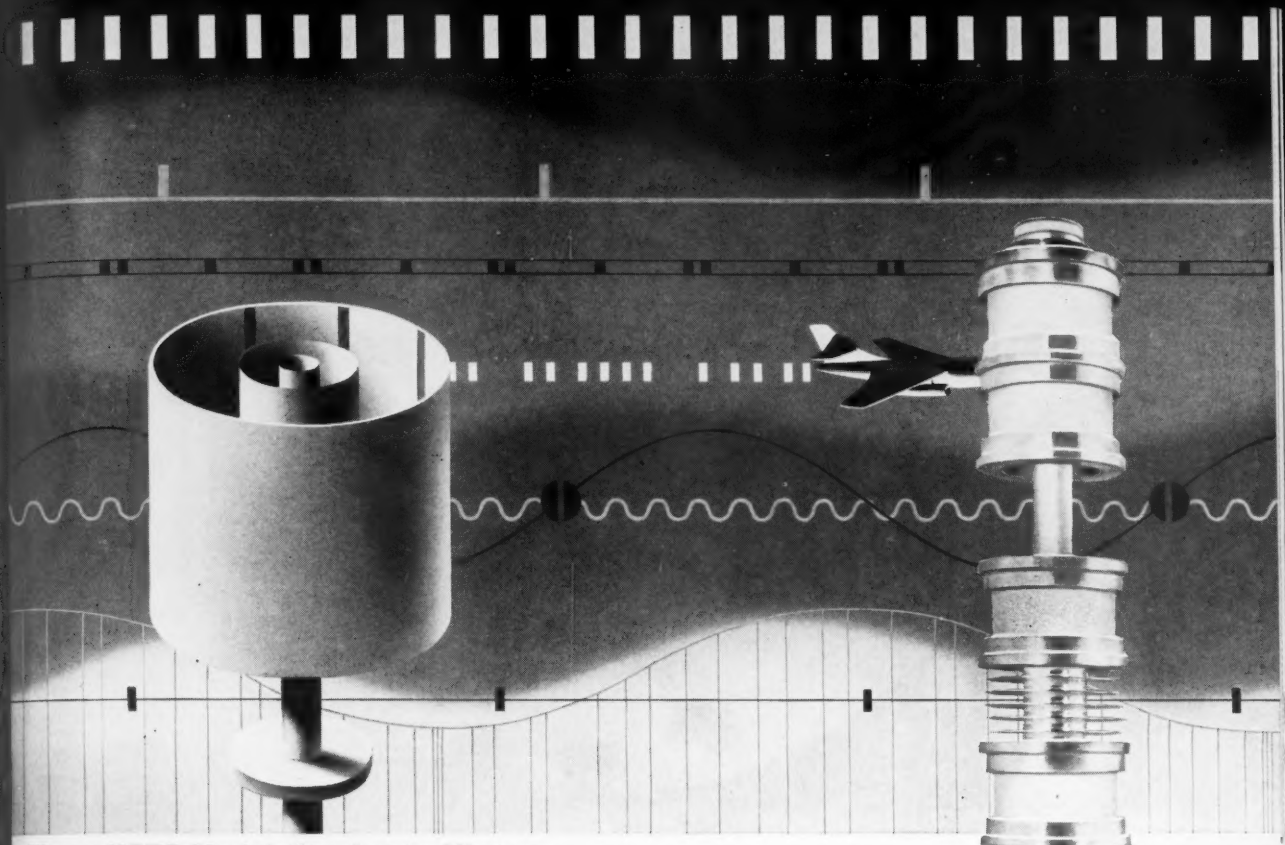


Eimac X676 Modulating Anode Klystron

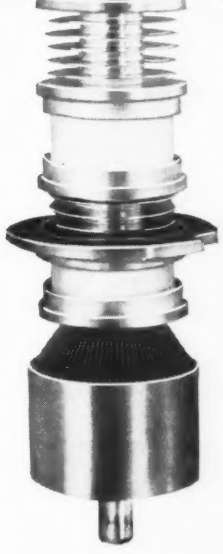
Eimac X676 Meets CAA Air Navigational Requirements

Designed for air navigation systems, the Eimac X676 three cavity, air cooled klystron will deliver 30 KW peak power output in the 955 to 1220 mc range. With a power gain of 35 db, this tube has an efficiency of 40 per cent.

A typical air navigation systems requirement is a shaped RF pulse output to eliminate spectrum interference in adjacent channels. The Eimac X676 conservatively meets the 60db requirement of the CAA's air navigational system without using critically tuned, expensive filters in the RF output transmission line. The modulating anode permits pulsing the beam current while keeping the accelerating voltage constant. Also, the modulator circuit for this application is quite simple.

The RF cavities are external to the vacuum system and detachable from the klystron. The user may purchase spare tubes without buying additional tuning and focusing assemblies.

For the design engineer, the features of the X676 simplify circuitry – for the equipment operators the X676 provides reliable, long-lived performance at moderate cost.



For further information about the Eimac X676 Modulating Anode Klystron, consult our Application Engineering Department. Also available are two highly informative booklets; "The Care and Feeding of Klystrons" and "Klystron Facts . . . Case Four".

EITEL-McCULLOUGH, INC.
SAN BRUNO CALIFORNIA

***Eimac First* in high power amplifier klystrons**

Eimac

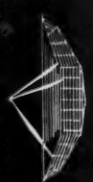
Typical Pulse Operation X676

DC Beam Voltage	24 KV	Power Output	32 KW	Power Gain	35 db
*DC Beam Current	3.3 Amps	Driving Power	10 watts	Average Power	1 KW
Power Input	80 KW	Efficiency	40%		

Leadership: Avionics Design and Packaging

COLLINS in GROUND COMMUNICATION

Collins engineers, designs and supplies the equipment, installs, and puts into operation integrated point-to-point communication systems of any scope. The Collins system engineering staff is backed by the finest equipment in the world, whether standard MF, HF or VHF, Transhorizon "scatter," microwave relay and multiplex or single sideband HF. Typical of Collins communication progress is "Kineplex" — a high speed data transmission system doubling communication capacity.



COLLINS in AMATEUR RADIO

In the early 1930's Collins set the standard in Amateur radio and, through continuous design and development, has raised this standard to its present single sideband station — the most honored and prized in the Amateur fraternity. This station is the top performing rig on the air with its kilowatt KWS-1 transmitter and highly selective 75A-4 receiver. Many of the leaders in the electronics industry became acquainted with Collins through the Company's superior Amateur equipment.

Collins

CREATIVE LEADER IN AVIATION ELECTRONIC

CNI

Communication
Navigation
Identification

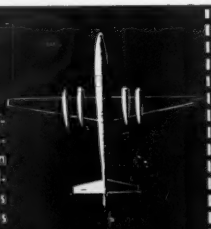
Collins CNI is an efficient electronics package designed to each aircraft type and provides a common logistics base by utilizing identical modules for all aircraft.

Advanced packaging techniques plus increased attention to problems regarding vibration, heat transfer and mutual interference have led to development of the Collins-designed AN/ASQ-19 Integrated Electronics System.

McDonnell Aircraft Corporation, first to use this design, has been instrumental in proving and refining the system.

COLLINS in AVIATION

Collins completely outfits airline, military and business aircraft with the most advanced communication, navigation, flight control and instrumentation systems in aviation. Many new lightweight, reduced-size versions are now being delivered. Collins designed the original Integrated Flight System, leads in combining comm/nav/ident units into a single compact "CNI" package for new military aircraft, and continues to pace the industry in developments in airborne radar, ADF, ILS, VOR, HF and VHF communication.



COLLINS in COMPONENTS AND TEST EQUIPMENT

The degree of precision and reliability of Collins products requires development by Collins engineering of components such as Autotunes and Autopositioners, Mechanical Filters, oscillators, heat reducing tube shields and ferrites. These developments and other high quality components are sold by a Collins subsidiary, Communication Accessories Company of Hickman Mills, Missouri. The same principles of accuracy and reliability apply to Collins test equipment, built especially for Collins but adaptable to testing other equipment types.

COLLINS

COLLINS RADIO COMPANY, CEDAR RAPIDS, IOWA • DALLAS • BURBANK • NEW YORK
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NAVY
NAVY
59

First U.S. production aircraft with boundary layer control—the new Lockheed T2V-1 SeaStar

9 OUT OF 10 U.S. MILITARY JET PILOTS WERE TRAINED IN LOCKHEED JETS. THE LARGEST ORDER FOR CARRIER-BASED JET TRAINERS IN U.S. NAVY HISTORY WAS RECENTLY AWARDED LOCKHEED'S CALIFORNIA DIVISION.

— — — — —

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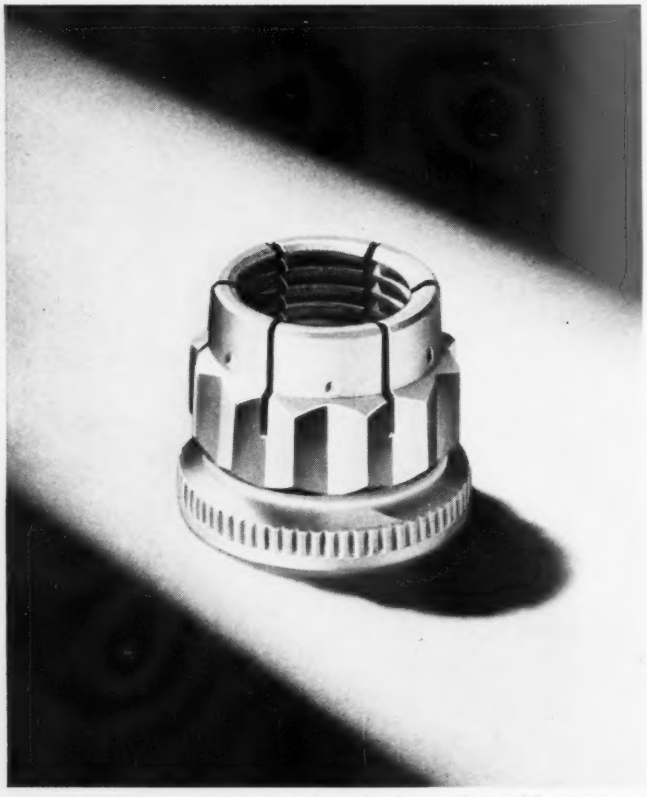
NEW—SPS 119 FW aircraft locknut for applications up to 1200°F



NEW SPS 119 FW self-locking nut is made of corrosion and heat-resistant alloys, silver plated. It incorporates the reliable SPS FLEXLOC self-locking feature, which locks the nut securely in place without auxiliary locking devices. These nuts are precision manufactured to Class 3B fit.

Critical components operating under high temperatures in jet engines—in manifolds, afterburners and similar hot spots—cannot be kept fastened with ordinary locknuts. In high temperatures, such nuts soften and fail from loss of tensile strength. They also seize after cooling. Often removal of the nuts can then be so difficult that the parts they hold together are damaged in disassembly.

SPS 119 FW high temperature locknuts were designed to end such problems. Made of corrosion and heat-resistant alloys, and silver plated to exact specification, they retain their high tensile strength in temperatures up to 1200°F. And they withstand hundreds of cycles of heating and cooling without galling or seizing on mating threads.

For complete information about SPS 119 FW 1200°F locknuts or the complete line of standard SPS threaded aircraft fasteners, or for assistance with your special aircraft threaded fastener problem, write us today. Aircraft Products Division, STANDARD PRESSED STEEL Co., Jenkintown 58, Pa.

AIRCRAFT PRODUCTS DIVISION

STANDARD PRESSED STEEL CO.

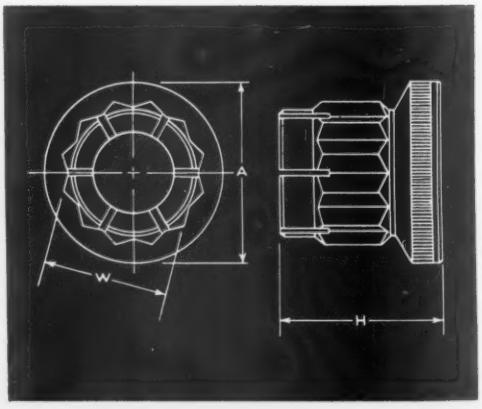
SPS

JENKINTOWN PENNSYLVANIA

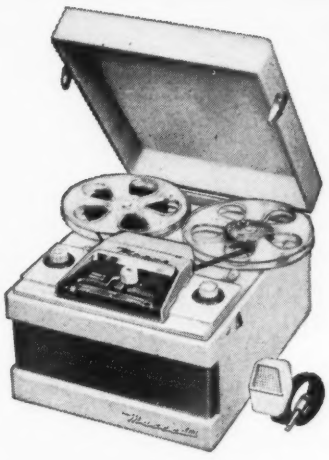
SPECIFICATIONS

Size	A ±.010	H ±.005	W max	W min
10-32	.375	.350	.313	.304
¼-28	.438	.406	.376	.367
5/16-24	.531	.468	.439	.430
3/8-24	.593	.500	.502	.492
7/16-20	.687	.570	.564	.553
½-20	.781	.604	.627	.616

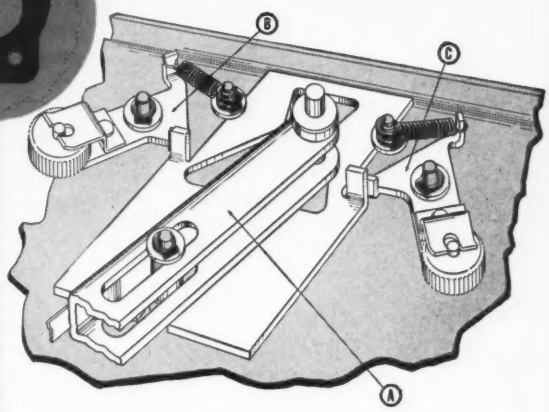
Standard sizes range from #10 to ½ in. diameter. Other SPS high temperature aircraft locknuts are available in larger sizes. Write for details.



Waldes Truarc grip rings used on die-cast studs eliminate threading, tapping, other costly machining



Mark Simpson Manufacturing Co., Long Island City, N. Y., uses Waldes Truarc series 5555 Grip Rings to secure parts to studs of the zinc die-cast base of its "Masco 500" portable tape recorder.
The rings—which need no grooves—replace nuts, screws, cotter pins and other types of fastening devices which require threading, tapping, drilling and other expensive machining operations. Because a single cracked or broken stud would render the entire cast base useless—and with it, all assembly completed to that point—the rings also eliminate extremely costly rejects.



Pivot Assembly of shift lever (A) is secured by a single Waldes Truarc Grip Ring and washer. Because the washer must be installed over the shift level in a sliding fit, critical tolerances would have to be maintained if a screw or cotter pin were used. The Truarc Grip Ring eliminates that problem: it requires no groove and may be seated over the washer at any point on the stud, automatically compensating for accumulated tolerances in the parts. BRAKE ASSEMBLIES (B and C) use Grip Rings to secure the brake wheel and spring subassemblies. Here again problems of critical tolerances are avoided and expensive rejects eliminated.

Whatever you make, there's a Waldes Truarc Retaining Ring designed to improve your product... to save you material, machining and labor costs. They're quick and easy to assemble and disassemble, and they do a better job of holding parts together. Truarc rings are precision engineered and precision made, quality controlled from raw material to finished ring.

36 functionally different types... as many as 97 different sizes within a type... 5 metal specifications and 14 different finishes. Truarc rings are available from 90 stocking points throughout the U. S. A. and Canada.

More than 30 engineering-minded factory representatives and 700 field men are available to you on call. Send us your blueprints today... let our Truarc engineers help you solve design, assembly and production problems... without obligation.

For precision internal grooving and undercutting... Waldes Truarc Grooving Tool!

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TRUARC®
RETAINING RINGS
WALDES KOHINOOR, INC.
47-16 AUSTEL PLACE, L. I. C. 1, N. Y.

Waldes Kohinoor, Inc., 47-16 Austel Place, L. I. C. 1, N.Y.
Please send the new supplement No. 1 which brings Truarc Catalog RR 9-52 up to date.
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AE059

WALDES TRUARC Retaining Rings, Grooving Tools, Pliers, Applicators and Dispensers are protected by one or more of the following U. S. Patents: 2,382,948; 2,411,426; 2,411,761; 2,416,852; 2,420,921; 2,428,341; 2,439,785; 2,441,846; 2,455,165; 2,483,379; 2,483,380; 2,483,383; 2,487,802; 2,487,803; 2,491,306; 2,491,310; 2,509,081; 2,544,631; 2,546,616; 2,547,263; 2,558,704; 2,574,034; 2,577,319; 2,595,787, and other U. S. Patents pending. Equal patent protection established in foreign countries.

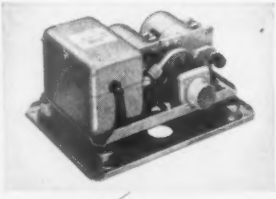
SEE THE TRUARC EXHIBIT AT THE DESIGN ENGINEERING SHOW, NEW YORK COLISEUM, MAY 20th TO MAY 23rd. BOOTH No. 1010.

Controlling the tornado of intake air consumed by supersonic jets is the latest assignment of Giannini's High Resolution Pressure Transducer. This versatile instrument plays a key role in maintaining optimum efficiency of today's newest and most advanced high performance turbojet engines.

Two of these transducers form the heart of the Giannini designed and produced Variable Inlet Control System which limits diffuser air to a steady subsonic flow at all speeds and altitudes. Static and total air pressures in the diffuser throat are sensed by absolute and differential versions of the transducer, and this data is transmitted to a computing element. The ratio of pressures is compared to a stable reference, and error signals are fed back to position a variable obstruction, or ramp, in the inlet duct.

By using these unique pressure instruments as sensing elements in the Giannini system, several distinct advantages result: the transducers can be located near the pressure probes, minimizing pneumatic tubing length; no stable amplifier is required since the high level output of the transducer potentiometer pickoffs can be used directly; no repeater servo is required; the system is flexible, control pressure ratio being altered merely by adjusting the reference; the computer can be located remote from the transducers.

The Giannini Variable Inlet Control System is typical of applications to which this instrument can be put. **Capabilities** of 350 volt output, 2000 wire resolution, 0.8% linearity, repeatability to 1% of *reading*, and its rugged insensibility to vibration and shock make it ideal for use in the most critical airborne controls and systems... In case you're not interested in taming a tornado—perhaps it's only a mild breeze—Giannini High Resolution Pressure Transducers are admirably suited for telemetering and control applications requiring the ultimate in accuracy and sensitivity.



Giannini Variable Inlet Control System

Write for Bulletin 451212.

Giannini PRECISION INSTRUMENTS & CONTROLS

G. M. GIANNINI & CO., INC. • 918 EAST GREEN STREET • PASADENA, CALIFORNIA

...By Jove!

ASW* is a Navy need in protecting our nation's supply lines . . . as guardian of our coast line . . . if the time ever comes when an underwater aggressor wants to pose his threat. Like Jove, god of the skies, the Navy's *Anti-Submarine Warfare techniques will be poised to seek and sink that threat . . . with a complete electronic search, track and kill package especially designed for the aircraft and the mission. ➢ ➢ For economical and operational efficiency, the LMEE "Tri-A" (Advanced Airborne ASW*) system will fill a true Jove-like function . . . in seeking the aggressor . . . and as a thunderbolt in destroying it. ➢ ➢ This is only one of many LMEE advancements in sonobuoys, displays and search systems. Along with the development and production sections in Utica, its Advanced Electronics Center at Ithaca, New York, is making important contributions to passive systems studies. Coordination between LMEE engineers and Naval research scientists can wipe out tactical advantages the submarine has traditionally enjoyed. Write Department F.

LMEE

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FRENCH ROAD, UTICA, NEW YORK

A DEPARTMENT OF THE DEFENSE ELECTRONICS TEAM

Flexon®

ducting and components

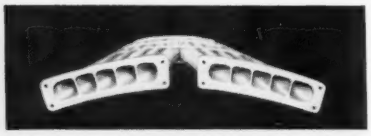
engineering and design briefs

Afterburner Cooling Assembly Gangs Straight Wall Tubing For High Strength, Light Weight

A minimum weight plus complex fabricating problems were critical factors in the development of this afterburner cooling blast tube assembly.

The space envelope was shallow and wide and over six feet long. The assembly was required to be tested at 28 psig with collapsing pressure of −2.5 psig and at a temperature of 250° F.

Flexonics answered the need by



End view of afterburner cooling assembly. Note rectangular shape of ends.

forming standard High Strength welded tubing into a gang. Ends of the tubes were formed to a rectangular shape to adapt them to the required end fittings. The tubes are held together with welded bands as the illustration of the unit shows. Tabs are provided for mounting in the airframe.

Tubing used in the assembly is 1.625″ O.D. by .011″ wall thickness. Type 321 High Strength stainless steel is used, with ultimate of 100,000 psi.

Facilities are the Key Factor

In the engineering, fabrication and proving of assemblies such as this, facilities are all important. As the pioneer and leading manufacturer of light weight corrosion resistant flexible assemblies and ducting, Flexonics Corporation has facilities second to none.

The engineering skill of Flexonics Corporation is proved by the scores of developments already made ranging from single flex connectors to entire aircraft ducting systems.

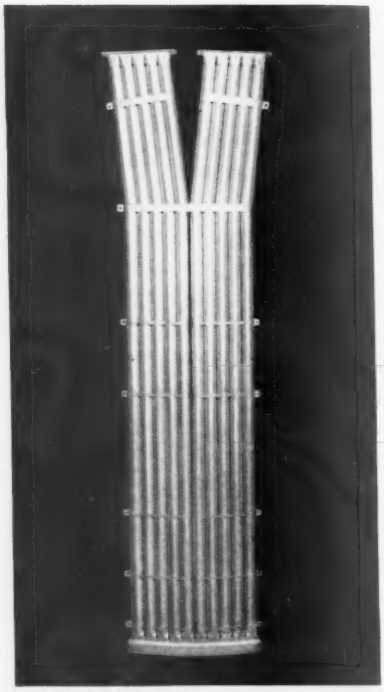
The manufacturing know-how of Flexonics Corporation is proved by the daily trouble free production of intricate assemblies and by such developments as the re-deposition process of forming ducting components.

The ability to prove assemblies before their installation in aircraft and engines is assured by the extensive Flexonics laboratories capable of the most advanced testing procedures.

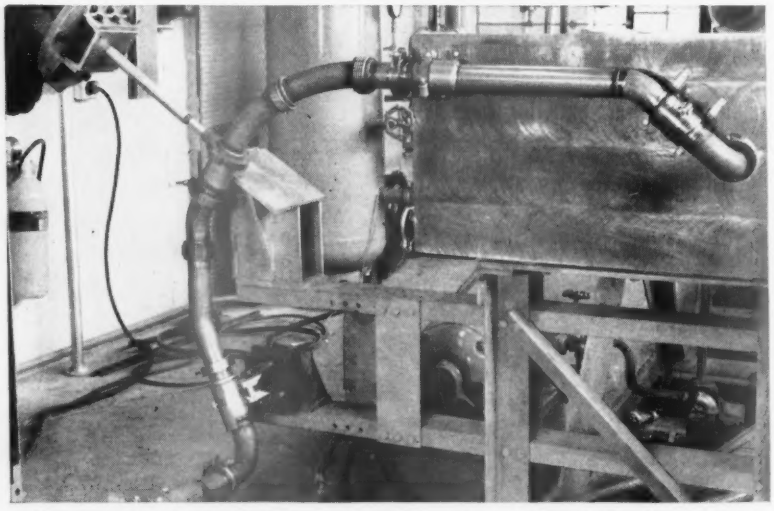
Engineering Assistance

Whenever you have a problem involving aircraft plumbing, take advantage of the know-how and facilities of Flexonics Corporation. For specific recommendations send an outline of your requirements.

For help right at your desk, write for information on how qualified persons can secure copies of the new Flexonics Engineering Manual.



Complete afterburner cooling assembly. Note use of straps to gang the tubing.



Ducting system test in the Flexonics labs. Shown is a portion of vibration and flow under pressure tests of assemblies in a bleed air system for a current fighter aircraft.

NOW, FROM FLEXONICS A COMPLETE LINE OF FLEXIBLE CONNECTORS AND DUCTING

With the acquisition of FLEX-O-TUBE Division, Flexonics Corporation is now able to offer a complete line of rubber, synthetic and Teflon hose assemblies and crimped-on and re-usable fittings. Write for full information.

AIRCRAFT DIVISION

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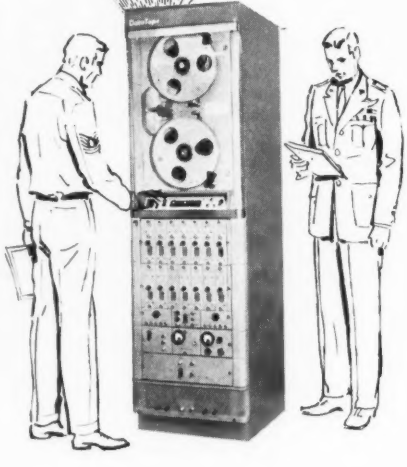
Also Manufacturers of: Industrial Hose • Expansion Joints • Bellows • Thermostats

While this missile is in flight...

...telemetered data are recorded and simultaneously played back for computer use



Developed to record and reproduce missile data, Consolidated's new 5-752 Magnetic Tape System is also ideal for wind tunnels, engine test stands—wherever high speed acquisition of large amounts of precise data is essential. A compact, complete Magnetic Tape Recorder and Reproducer System housed in one steel cabinet, the 5-752 handles analog, PDM, and FM signals... provides seven individual tape tracks for simultaneous recording of separate signals on ½-inch tape. It also handles ¼, ¾, and 1-inch tape widths with a capacity of 5000 feet of 1.5-mil tape.

CEC's new magnetic

TAPE RECORDER/REPRODUCER SYSTEM

Frequency range of the 5-752 is from 0 cycles to 100 kc. Six tape speeds are provided in three groups—60 and 30 ips, 15 and 7.5 ips, and 3¾ and 1⅞ ips, with switching selectable from the front panel. Contact your nearby CEC field office, or write for Bulletin CEC 1576-X3.

Consolidated Electrodynamics

300 North Sierra Madre Villa, Pasadena, California

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Frozen on the outside, warm and ready to go on the inside!

The "Mars" makes the difference*

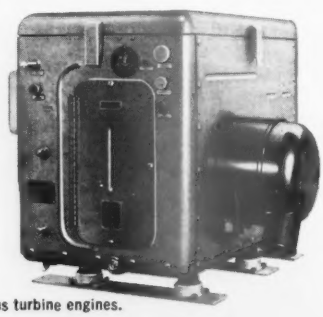
EXTREME COLD in Arctic operations has little effect on the compact, reliable Mars auxiliary power unit used on the Boeing KC-97 tanker. Often running continuously day in and day out, the dependable Mars-powered generator set keeps the cabin comfortable at below-zero temperatures. It supplies electric power also for engine preheating and starting systems as well as for other auxiliary equipment.

Solar's 50 hp Mars gas turbine is the heart of the airborne power unit. The Mars engine weighs less than 100 pounds, is smaller than a two-foot cube. It starts easily from 130F to –65F ambient temperatures, operates on a variety of fuels, is simple to maintain, and requires infrequent overhauls. In addition to the KC-97, Mars auxiliary power units are employed on the Douglas C-124C, the Lockheed C-121C and Convair C-131B.

Perhaps the Mars gas turbine can help solve your need for a light, compact, powerful engine. Write to Dept. D-12, Solar Aircraft Company, San Diego 12, California, for more data on the Mars gas turbine.

WRITE FOR BOOKLET

New brochure describes Solar gas turbines—how they work, advantages they offer. Ask for a copy.



SOLAR
AIRCRAFT COMPANY
SAN DIEGO
DES MOINES

*Mars is the registered trade mark for Solar's line of 50 hp gas turbine engines.

he's watching the progress of the Air Age from his machine...

Piston engines . . . jets . . . and now, missiles, Foote Bros. craftsmen are watching the steady advance of American air progress from their machines. They're not only watching it—they are an important part of it, because, at this moment they are helping produce components capable of performance undreamed of a short time ago.

At Foote Bros., yesterday's technology, methods and standards of precision are obsolete. Today, these men are working with new metals in new ways, with greater precision, to produce lighter, stronger and more reliable gearing, power transmission and actuating mechanisms for the air age of tomorrow.

It is the willingness to innovate, the ability to anticipate, and the determination to excel that have helped Foote Bros. engineers and production men keep pace with, and earn the confidence of, the aviation industry.

We may be able to help solve your problems involving precision gearing and actuating mechanisms, and would welcome the opportunity of talking with you.

this trademark stands for the finest industrial gearing made

FOOTE BROS. Duti-Rated LIFETIME GEARING

FOOTE BROS.

Better Power Transmission Through Better Gears

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Bell Aircraft is an organization in which the successful culmination of important projects has meant continual, sound expansion through the years. This growth, together with Bell's widely diversified fields of interest, offer exceptional opportunities for engineers and technicians as listed at the right—opportunities with horizons as broad as the universe and professional growth limited only by your own personal abilities. You'll never be slowed down by the lack or limited scope of projects at Bell.

For further information regarding employment opportunities in the Weapon Systems Division or the Aircraft Division of Bell Aircraft, write today: Manager, Technical Employment, Dept. A21, Weapon Systems Division.

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- Physicists
- Power Plant Designers
- Pressure Vessel Designers
- Project Engineers
- Publication Engineers
- Radar Systems Engineers
- Reactor Designers
- Reliability Engineers
- Rocket Test Engineers
- Servo Systems Engineers
- Servo Valve Engineers
- Statisticians
- Stress Engineers
- Structures Engineers
- Specification Writers
- Technical Writers
- Test Equipment Engineers
- Transformer Design Specialists
- Transistor Application Engineers
- Thermodynamic Engineers
- Telemetering Engineers
- Turbine Pump Designers
- Vibration & Flutter Analysts
- Weapons Systems Engineers
- Wave Guide Development Engineers
- Weights Engineers

Johns-Manville structural insulations offer you unparalleled design flexibility

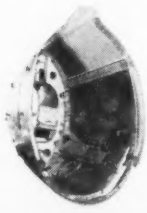
Proof of this design flexibility can be seen in the intricately designed structural insulations Johns-Manville is now producing for the aviation industry.

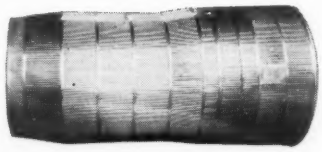
Precision formed through recently developed methods, Johns-Manville structural insulations meet the exacting design specifications of aircraft manufacturers. They provide the closer temperature control needed for supersonic performance. And—equally important—they are integral structural parts that resist vibration and corrosion to keep maintenance and replacement at a minimum.

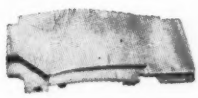
J-M aircraft and missile insulations are made of high-heat resistant alloys enclosing Thermoflex® refractory fiber felt. The finished part is light in weight, yet possesses unusual structural strength and rigidity.

So whether you're in the blueprint stage or in prototype testing, whenever and wherever you need HEAT control—call in J-M. Our insulation specialists will give you the design help you need . . . the very latest information on insulation methods employing stainless steel, titanium and other light-weight, heat-resistant alloys.

Write Johns-Manville, Box 14, New York 16, N. Y. In Canada, Port Credit, Ont.


Insulated Structural Panel Assembly


Insulated Engine Shroud


Insulated Structural Part

Johns-Manville PRODUCTS FOR THE AVIATION INDUSTRY

PANALOG PANELLIT PSC SERVICE CORP.

PANELLIT, INC.

7519 N. Hamlin Ave., Skokie, Ill.
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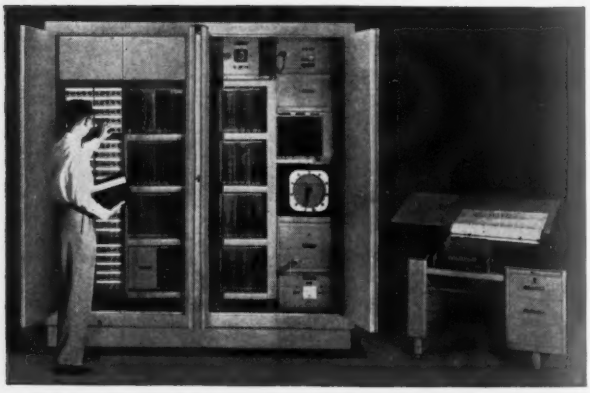
Panellit of Canada Ltd. Toronto 14

PANELLIT PANALARM

ENGINEERED INFORMATION SYSTEMS FOR INDUSTRY



PANALOG INFORMATION SYSTEMS

Panalog Information Systems provide complete, centralized process control to management. The system is designed to feed data to electric typewriters . . . directly, without human translation, to calculators for automatic accounting operations . . . or to computers for on-the-spot engineering analysis.

The Panalog Information System incorporates continuous process monitoring with audio-visual annunciation, periodic or "on-demand" logging of up to several thousand variables, immediate logging of both "off-normal" and "return-to-normal" occurrences, selectional trend recording and complete process control.

Logging is arranged by processing unit, rather than type of variable, so that a clear picture is presented for operating decisions.

Panellit furnishes a complete service from basic system design and engineering to final installation, check-out and service. **Send for literature.**

PANALARM PROCESS ANNUNCIATOR SYSTEMS

Panalarm Annunicator Systems, the recognized standard in the process field, are available in numerous forms to fulfill all specific requirements.

Panalarm Annunciator Systems provide both a visual and audible signal when an "off-normal" condition develops. Panalarm "50" models provide the most versatile form of annunciation available today. Fulfill the requirements of every usual process application. **Send for literature.**

PANELLIT CO-ORDINATED CONTROL PANELS

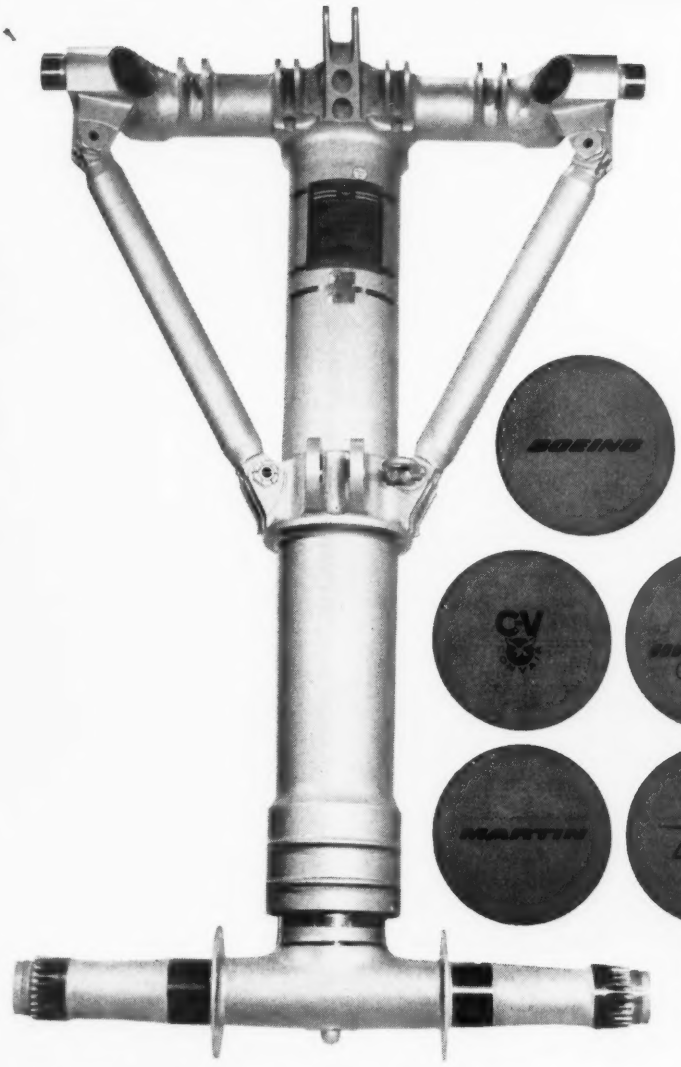
Panellit is the largest builder of process control panels. Specialized experience in this field enables Panellit to provide valuable engineering assistance. Panellit behind-the-panel engineering, incorporating clear, traceable piping and individual equipment enclosures assures maximum serviceability of your control system. **Send for literature.**

PANELLIT SERVICE CORPORATION—"PSC"

Panellit Service Corporation provides a single responsible service for instrumentation systems—survey, engineering, construction (startup and commissioning), and maintenance. "PSC" is staffed with a corps of highly skilled, experienced instrument specialists. **Send for literature.**

Why Choose menasco ?

...Because "BLUE CHIP" *Customers Demand* "BLUE CHIP" *Specialists in Aircraft Landing Gear*



MENASCO is justly proud to be closely associated with these great aircraft manufacturers. Their choice of MENASCO Landing Gear reflects their conviction that they are the very best obtainable for all types of civilian and military aircraft. MENASCO Landing Gear is adaptable to every kind of installation.

The preference for MENASCO Landing Gear to perform the vital functions of takeoff and landing is based upon a number of reasons... the exclusive *Uniwelding* process assures greater strength... MENASCO designs utilize the most effective application of high strength steels, aluminum and titanium for lighter weight and compactness. MENASCO assures *reliability* and *ruggedness* through the highest standards of quality control and thorough operational testing.

first in development, quality, delivery and service.

SPECIALISTS IN AIRCRAFT LANDING GEAR

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BURBANK, CALIFORNIA • FORT WORTH, TEXAS

AIRCRAFT COSTING MILLIONS...

ING PHOTO

...ARE PROTECTED BY THE B&H

JETCAL® ANALYZER

Two of the most important factors that affect jet engine life, efficiency, and safe operation are *Exhaust Gas Temperature (EGT)* and *Engine Speed (RPM)*. Excess heat will reduce "bucket" life as much as 50% and low EGT materially reduces efficiency and thrust. Any of such conditions will make operation of the aircraft both costly and dangerous. The *JETCAL Analyzer* predetermines accuracy of the EGT and (interrelatedly) Tachometer systems and isolates errors if they exist.

The *JETCAL* ANALYZES JET ENGINES 10 WAYS:

1) The JETCAL Analyzer *functionally* tests EGT thermocouple circuit of a jet aircraft or pilotless aircraft missile for error *without running the engine or disconnecting any wiring*. GUARANTEED ACCURACY is ±4°C. at engine test temperature.

2) Checks individual thermocouples "on the bench" before placement in parallel harness.

3) Checks thermocouples within the harness for continuity.

4) Checks thermocouples *and* paralleling harness for accuracy.

5) Checks resistance of the Exhaust Gas Temperature system.

6) Checks insulation of the EGT circuit for shorts to ground and for shorts between leads.

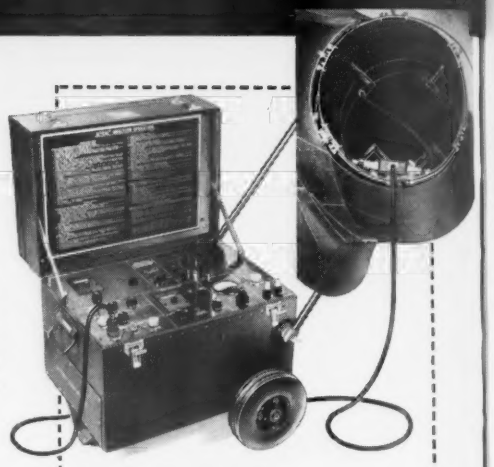
7) Checks EGT Indicators (in or out of the aircraft).

8) Checks EGT system with engine removed from aircraft (in production line or overhaul shop).

9) Reads jet engine speed while the engine is running with a guaranteed accuracy of ±0.1% in the range of 0-110% RPM. Additionally, the TAKCAL circuit can be used to trouble shoot and isolate errors in the aircraft tachometer system.

10) JETCAL Analyzer enables engine adjustment to proper relationship between engine temperature and engine RPM for maximum thrust and efficiency during engine run (Tabbing or Micing).

ALSO *functionally* checks aircraft Over-Heat Detectors and Wing Anti-Ice Systems (thermal switch and continuous wire) by using TEMPCAL Probes.. Rapid heat rise . . . 3 minutes to 800°F! Fast cycling time of thermal switches . . . 4 to 5 complete cycles per minute for bench checking in production.



Tests EGT System Accuracy to ±4°C at Test Temperature

(functionally, without running the engine)

Tests RPM Accuracy to 10 RPM in 10,000 RPM (±0.1%)

The JETCAL is in worldwide use . . . by the U. S. Navy and Air Force as well as by major aircraft and engine manufacturers. Write, wire or phone for complete information.

B & H INSTRUMENT CO., INC.

3479 West Vickery Blvd. • Fort Worth 7, Texas

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WHY DOUGLAS ENGINEERS AND SCIENTISTS GO FURTHER...

At DOUGLAS, your career in missiles is backed by sixteen years of experience and an ever-expanding future

The finest talents and facilities in the industry have earned an outstanding position for Douglas in the national missile program.

You will become part of a team that has contributed more to the research, design, development and production of missiles than any other group in the nation.

You will work on projects that challenge the imagination... that stretch out far into the future ... that let you plan a secure and rewarding career with Douglas. Many of these projects have their roots in the mid-forties and are still growing.

Close coordination of missile and aircraft work provides an interchange of experience and knowledge among Douglas engineers and scientists. All plants are engaged in some phase of this missile program... making possible a broad choice of locations where you can work and establish living conditions suited to your taste.

For complete information, write:
E. C. KALIHER,
MISSILES ENGINEERING PERSONNEL MANAGER,
DOUGLAS AIRCRAFT COMPANY, BOX 620-Z,
SANTA MONICA, CALIFORNIA

THIS IS NIKE HERCULES, a surface-to-air missile newly developed out of the original Nike system started in 1945 — a major project in the Douglas missile program.

GO FURTHER WITH DOUGLAS

FIRST IN AVIATION

Can you use the talent that built 1,500 Y-4 bombsights on schedule?

These General Mills technicians are representative of the production talent that built more than 1,500 Y-4 bombsights, 1,500 coordinate converters, 1,400 azimuth and sighting angle indicators and 1,400 amplifier and power supply units—and, delivered them to the Air Force *on time*. Here the men inspect a bombsight before it progresses to the next stage of production.

Because we have the highly skilled men—and the men have the specialized tools and machines—we produce precision piece parts or complete, complex assemblies to meet the most exacting requirements.

While building the Y-4 bombsight, we improved original design, exceeded USAF specifications. In addition, our thorough testing facilities assured delivery of only perfect instruments.

Such performance has come to be expected of us and has benefited many other customers. We'd like to help with your production problems too.

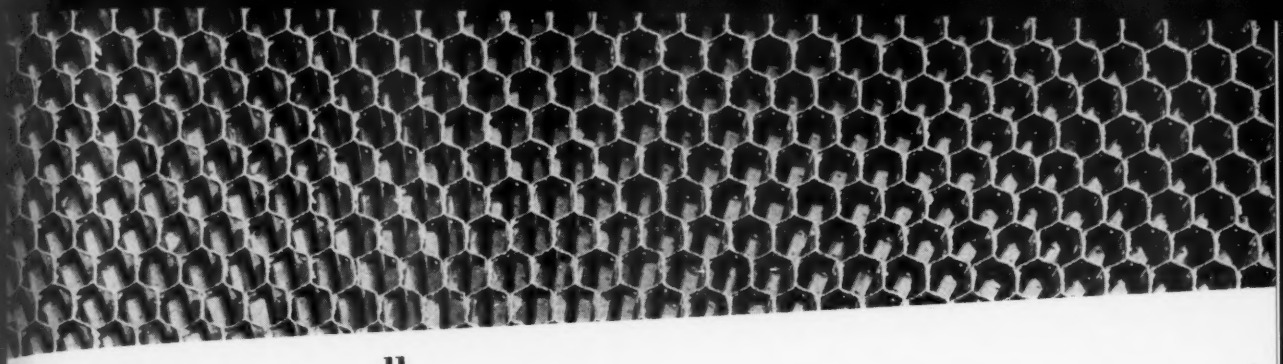
Booklet Tells More, explains mechanical and electro-mechanical production facilities. Send to Dept. AR-5, Mechanical Division, General Mills, 1620 Central Ave. N.E., Minneapolis, Minn.

No slow-downs for the B-47—Bombsights ready in advance! During production of the B-47 Stratojet, not a one was kept from the ready-line for lack of a bombsight. The same developmental, engineering and production skills that gave the Air Force on-time delivery are available to speed production of your products.

MECHANICAL DIVISION

CREATIVE RESEARCH AND DEVELOPMENT + PRECISION ENGINEERING AND PRODUCTION

General Mills



Swedlow ACQUIRES HONEYCOMB STRUCTURES COMPANY!

Here's NEWS *of importance to you!*

Giving you a reliable source for aluminum honeycomb cores and fabricated parts . . .

Swedlow Plastics Company is pleased to announce the recent acquisition of controlling interest in the assets, engineering and manufacturing facilities, techniques, and patents of Honeycomb Structures Company, Inc. of Los Angeles. Existing facilities will be retained, improved, and expanded.

The addition of honeycomb structural materials to Swedlow's decorative and industrial laminated plastics and heat resistant materials is a natural development and opens new fields for these interesting materials that are being used to an ever expanding degree by industry.

Sale of honeycomb core material will be handled by a newly formed "Core Division", and the sale of fabricated parts by the "Bonded Structures Division" of Swedlow Plastics Company. This now puts the combined engineering services of Swedlow and the former Honeycomb Structures Company at your disposal.

We welcome your inquiry on specific applications for these new materials.

Swedlow aluminum honeycomb material is available in a variety of core designs, sizes & thicknesses for applications such as . . .

Partition Panelling
Flooring
Stabilizers
Missile Fins
Tow Targets
Tail Assemblies
Ducting
Pressurized Tanks
Radar Vans
Microwave Reflectors
Electronic Gear Housings
Heat Exchangers
etc.

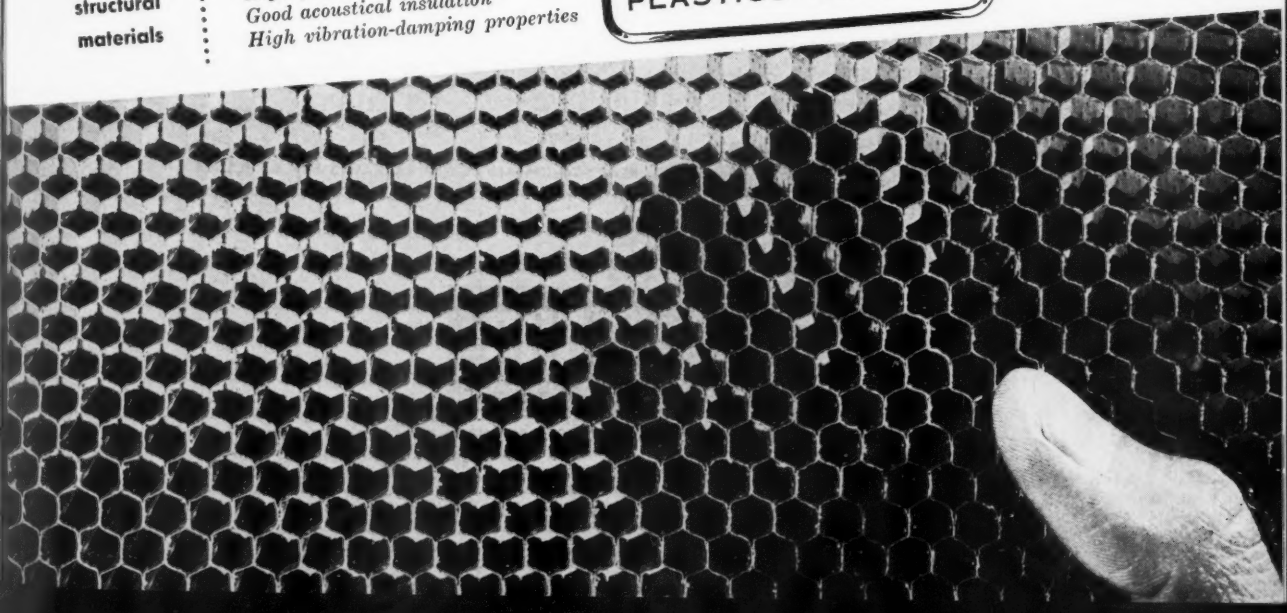
Advantages of honeycomb structural materials

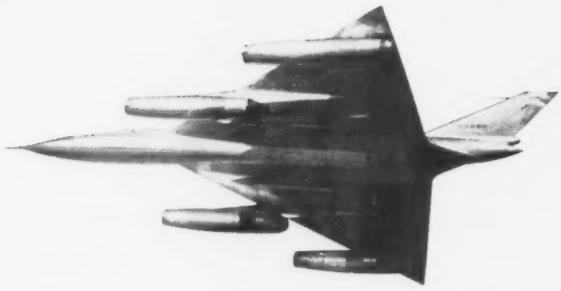
High strength-weight ratio
High rigidity-weight ratio
Good thermal resistance
High fatigue resistance
Good acoustical insulation
High vibration-damping properties

Swedlow
PLASTICS COMPANY

Los Angeles, California
Youngstown, Ohio

Please refer to Dept. 13





MORE AND MORE

MAJOR COMPONENTS

ARE BUILT BY ROHR

For example, brazed, stainless steel, honeycomb panel structures are being manufactured by Rohr for the great new B-58 Hustler, built by Convair for the U. S. Air Force.

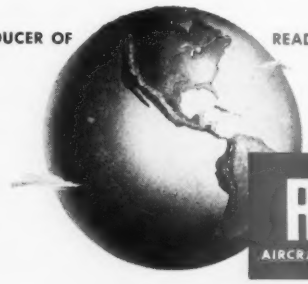
Today Rohr manufactures over 30,000 airplane parts, included in such major components as stabilizers, elevators, fuselage sections, pneumatic system components, high strength weldments, and stainless steel honeycomb sandwich panels.

More and more, leading air-frame manufacturers count on Rohr for design engineering, for conception, development and production of parts to meet modern flight problems. In many cases, Rohr engineering teams are actually assigned to the customer's plant, to work with the manufacturer's engineering staff and bring back a full understanding of requirements to be met.

And, of course, Rohr is well known as the world leader in production of ready-to-install power packages for airplanes – including the Boeing B-52, KC-135, 707, Convair 880, Lockheed Electra Propjet, Super Constellation, C-130, Douglas DC-7 – and many other of America's leading military and commercial planes.

For the aircraft parts you need, next time look to Rohr.

WORLD'S LARGEST PRODUCER OF READY-TO-INSTALL POWER PACKAGES FOR AIRPLANES



ROHR
AIRCRAFT CORPORATION

Excellent career openings now for engineers and tooling technicians.

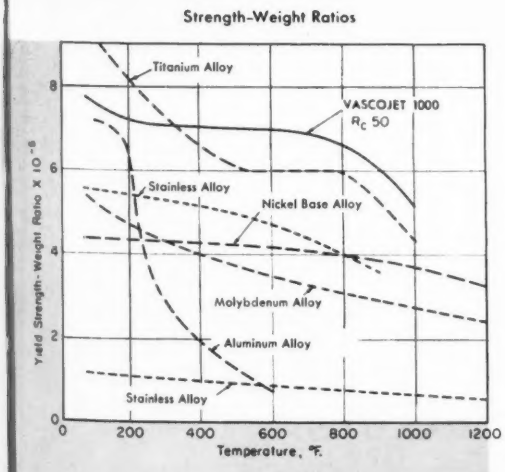
CHULA VISTA, CALIFORNIA

Also plants in Riverside, California • Winder, Georgia • Auburn, Washington

VASCOJET 1000

A new ultra high strength steel

presenting the highest strength-to-weight ratio at elevated temperatures *of any engineering material*



Now available for aircraft, ordnance and industrial applications, VASCOJET 1000 is a moderately-priced ultra high strength alloy steel possessing extraordinary properties. ● This steel is stable to 1000°F, surpassing in strength-to-weight ratio the best titanium and hardenable stainless alloys. It is of great importance for super-speed aircraft structures and skins, high-temperature fasteners and rotors. ● VASCOJET 1000 in normal temperature service at strength levels of 260,000 to 290,000 psi has the toughness, transverse ductility, fatigue strength* and freedom from residual stress that make it ideal for heavy-duty applications. Typical among these are aircraft landing gear, air frames, engine mounts, arresting gear and other critical components; fasteners, springs, pressure vessels; truck, train, airborne and portable equipment parts. ● VASCOJET 1000 is available in plate, sheet, strip, bars, extruded shapes, wire and forging billets. Write for comprehensive technical data.

*highest of any material reported

Vanadium-Alloys Steel Company

LATROBE, PENNSYLVANIA

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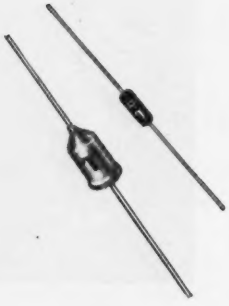
Transitron

Silicon

Transitron's diodes, voltage regulators and rectifiers are designed to operate over wide environmental extremes and meet the many varied requirements of electronic circuitry. Reliability is assured through hermetic sealing and exacting manufacturing standards.

Transitron's silicon units have established a record of dependability in such critical applications as guided missiles and jet aircraft. They feature low inverse leakages and high voltage operation and are recommended for high temperature applications where germanium and selenium are unreliable.



- **Current ratings up to 2 amps**
- **Superior regulating qualities**
- **Rugged construction**
- **Small size**
- **Axial mounting**

Send for Bulletin TE-1352

VOLTAGE REGULATORS

	Type	Voltage Range	Dynamic Resistance	Maximum Current @ 25°C (ma)	Maximum Current @ 125°C (ma)
Subminiature	SV-6	5.2 - 6.4	20	40	8
	SV-9	7.5 - 10.0	15	25	5
	SV-15	13.5 - 18.0	120	14	3
	SV-24	20.0 - 27.0	300	10	2
Miniature	SV-805	5.2 - 6.4	20	120	24
	SV-808	7.5 - 10.0	15	75	15
	SV-815	13.5 - 18.0	120	40	8
	SV-824	20.0 - 27.0	300	27	5
				(amps)	(ma)
Power	SV-905	5.2 - 6.4	.7	1.6	400
	SV-908	7.5 - 10.0	.8	1.0	250
	SV-915	13.5 - 18.0	3.0	.6	150
	SV-924	20.0 - 27.0	8.0	.4	100

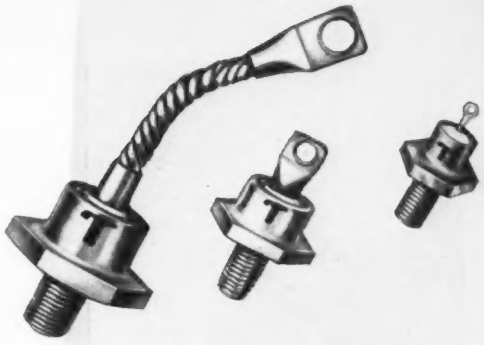
"Leadership in semiconductors"

Germanium Diodes | Transistors | Silicon Diodes | Silicon Rectifiers

RECTIFIERS

	Type	Maximum Inverse Voltage	Maximum Forward Current (ma) @ 150°C	Maximum Inverse Current (ma) @ 150°C
Military	*1N256	570	200	.25
	*1N255	380	400	.15
	*1N254	190	400	.1
	*1N253	95	1000	.1
Miniature	TJ40A	400	200	.5
	TJ30A	300	200	.5
	TJ20A	200	200	.5
Stud Mounted	TM64	600	1000	.5
	TM47	400	3000	.5
	1N332	400	400	.2
	1N338	100	1000	.2
			(amps)	(ma)
Medium Power	TR402	400	20	5
	1N250A	200	20	5
	1N249B	100	20	5
High Power	TH402	400	35	5
	1N413A	200	35	5
	1N412A	100	35	5

*JAN types specified at 135°C



- Reliability at high temperature
- High power handling ability
- High efficiency
- Rugged construction
- Hermetic sealing

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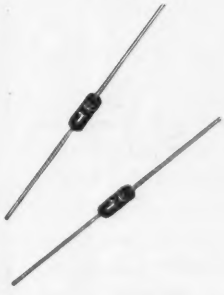
DIODES

	Type	Maximum Operating Voltage (volts)	Maximum Average Forward Current (ma) (@ 150°C)	Maximum Inverse Current (ua) @ volts (@ 150°C)
Military	*1N457	60	25	5 @ 60
	*1N458	125	25	5 @ 125
	*1N459	175	25	5 @ 175
High Conductance	1N484B	130	50	5 @ 125
	1N486A	225	50	25 @ 225
	1N488A	380	50	25 @ 380
			(@ 125°C)	(@ 125°C)
High Frequency	*1N251	30	30	10 @ 10
	1N252	20	40	10 @ 5
	S9G	40	25	10 @ 20
	Recovery time .15 usec			
			(@ 100°C)	(@ 100°C)
Fast Switching	SG213	200	12	50 @ 175
	SG211	80	12	20 @ 60
	Recovery time .3 usec			
	SG228	200	35	50 @ 175
	SG226	80	35	20 @ 60
	Recovery time 1 usec			

*JAN types



- Recovery times under .15 us
- High voltage ratings
- Operation up to 200°C
- High inverse resistance
- Subminiature size

Send for Bulletin TE-1350

Visit us at IRE Show Booth 3912-14

Transitron electronic corporation

wakefield, massachusetts

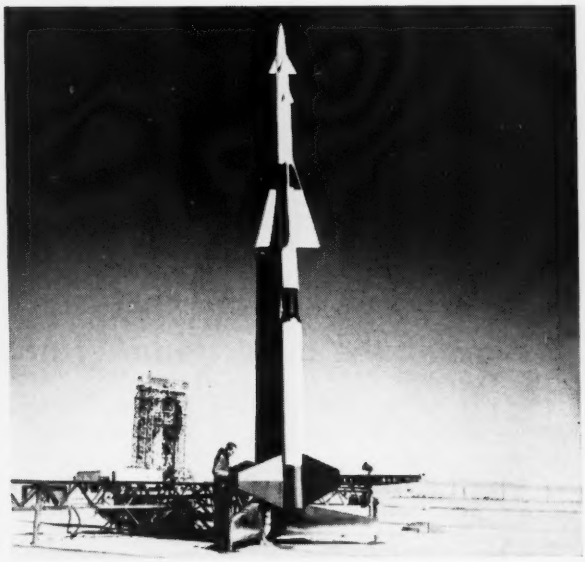
The first men on the moon

What Douglas engineers are doing to make it possible!

Space travel, a dream five years ago, is now so near reality that lunar landings are predicted by the end of this century.

This is hastened by knowledge being gained in *present* and *practical* research. For instance, when Douglas engineers find new ways for fliers to survive high gravitational pulls at supersonic speeds, they also help some future pilot survive the blast-off of a moon-bound rocket. And current studies on heat dispersion, aimed at getting an intercontinental missile back into our atmosphere without air friction burning it up, will apply to the problem of returning a space ship safely to earth.

With the possibility of interplanetary flight accepted by engineers, man now looks to outer space and is speculating on new power sources needed to get him there. A predicted break-through is the plasma engine, which will harness ions or light itself to drive aircraft nearly 186,000 miles per second.



At Douglas, a Missiles Division with the longest history in its field, is building rockets and missiles for military use. Nike Ajax (above) is already guarding principal cities, and soon the more potent Nike Hercules will be ready to take over these assignments. Thor, an intermediate range ballistics missile, is undergoing tests, and on the classified list are many other out-of-this-world projects in engineering, design and construction.

Depend on

DOUGLAS

first in Aviation

Transonic wind tunnel at Ohio State University is one of many facilities available to NAA engineers for advanced research.

Forward-looking Engineers: Work in the mainstream of aeronautical development

At North American Aviation's Columbus Division you will be part of a major aircraft engineering organization which commands facilities that rank among the finest in the world. Inside the plant itself the Engineering Department has at its disposal 16 fully equipped research laboratories, plus a wind tunnel now under construction. In addition, nearby Ohio State University cooperates in special research programs. Here also, many of our colleagues pursue graduate studies for their own professional advancement with the aid of our generous Educational Refund plan.

Situated within a 500 mile radius of most of the nation's finest aviation research and development facilities, the Columbus Division is in the very mainstream of today's technological progress. Full responsibility for all North American's Naval Aircraft projects is vested here, from concept to flight. This includes jet trainers such as the T2J... combat weapons such as the FJ-4 fighter and A3J attack weapons system... and others, even more advanced, still to come.

You'll enjoy working on challenging assignments like these, in an atmosphere of free interchange of advanced ideas among a group where initiative is encouraged and rewarded. Here are the fields of opportunity:

Advanced Performance Prediction · Aeroelastic Loads Analysis · Aircraft Guidance and Control Systems · Analog and Digital Computing · Electrical Systems Design · Electro-Mechanical Systems · Flutter and Vibration Analysis · Heat-Vent Systems · Human Factors · Military Operations Research · Missile Guidance Systems · Power Plant Installation · Propulsion Systems Analysis · Radome Development · Structural Loads Analysis · Thermodynamics · Weapons Systems Evaluation · Wind Tunnel Testing and Data Analysis.

Write: J. H. Papin, Engineering Personnel Manager, Dept. 56 AER-5, North American Aviation, Inc., Columbus 16, Ohio.

THE COLUMBUS DIVISION OF

NORTH AMERICAN AVIATION, INC.

New Airborne capacitors and filters are

smaller, lighter • • •

aid miniaturization of electronic devices

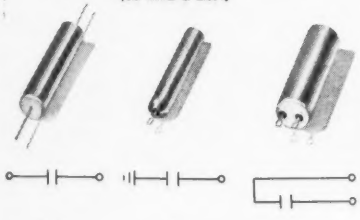
MINIATURIZED CAPACITORS

Utilizing Mylar dielectric and a special conductor, Airborne miniaturized capacitors offer microfarad ratings up to 12 times higher than those of ordinary capacitors of comparable size and weight. Vacuum impregnated and hermetically sealed in drawn steel cans or epoxy sleeves, they have excellent resistance to vibration, fungi, salt spray and humidity.

Airborne standard miniaturized capacitors are rated 200 v d-c and have an operating temperature range of —75°F to +300°F with only 12% capacitance change. At 300°F they withstand 150% rated voltage for 250 hrs. through a resistance of 1 ohm per volt.

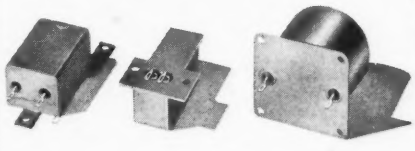
Where standard designs are not suitable, Airborne can produce special capacitors to meet your requirements. These custom miniatures likewise offer the advantage of reduced size and weight without sacrificing capacitance or dielectric strength. Typical is one of our new starting capacitors which is 75% lighter yet has twice the capacity and three times the dielectric strength of the old-style capacitor it replaced.

STANDARD CAPACITORS
(to MIL-C-25A)



Style "A" Style "B" Style "C"

TYPICAL SPECIAL CAPACITORS
(to JAN-C-25, MIL-1-6181B, MIL-M-8609)



E-8109 Style E-8104 Style E-8107 Style

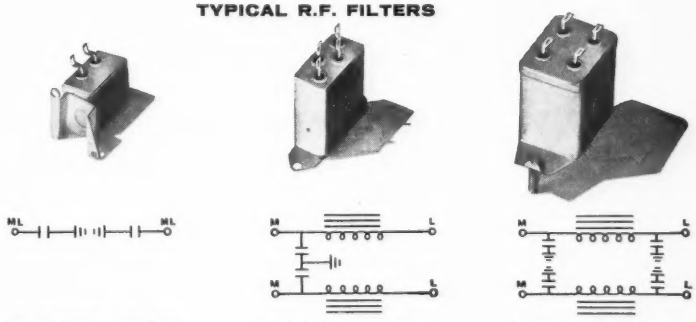
Airborne Standard Miniaturized Capacitors—200 v d-c

Microf. ±10%	Dia.	Length
.25	3/8	1-1/4
.5	1/2	1-1/4
1.0	5/8	1-1/4
3.0	7/8	1-1/8
4.0	1	1-1/8
5.0	1-5/32	1-1/8
6.0	1-1/4	1-1/8
7.0	1-5/16	1-1/8
8.0	1-29/64	1-1/8
9.0	1-1/2	1-1/8
.25	3/8	3/4
.4	1/2	3/4
.75	5/8	3/4
1.5	1	3/4
18.0	1-3/4	2-1/4

MINIATURIZED R.F. FILTERS

Airborne miniaturized r.f. filters also utilize Mylar dielectric and a special conducting material to reduce size and weight without compromising performance. Cores are molded to achieve maximum inductance with minimum bulk. Vacuum impregnated with polyamide resin; hermetically sealed in steel cans with glass terminals, Airborne miniaturized r.f. filters are serviceable from —75°F to +300°F. They meet JAN-C-25, MIL-1-6181B, and MIL-M-8609 and are available to your specifications. Typical standard constructions and circuits are shown at right, along with pertinent data on the motors to which these filters were matched. Mounting brackets are furnished to meet your requirements.

TYPICAL R.F. FILTERS



For 1.125 dia. split field series motor
No load current—.45 amp
Stall current—2.0 amp 100 v d-c
Comm-bar frequency—14 x 2700 rpm
Electro-graphitic brush

For 1.562 dia. split field series motor
No load current—2.8 amp
Stall current—18.5 amp
Comm-bar frequency—14 x 32000 rpm
Electro-graphitic brush

For 2.2 dia. split field series motor
No load current—3.7 amp
Stall current—45 amp
Comm-bar frequency—14 x 18000 rpm
Electro-graphitic brush

Write for latest technical bulletin on Airborne miniaturized capacitors and filters

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X-ray inspection of vital aircraft landing gear parts. Westinghouse now distributes portable Balteau line.

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Radiographic inspection of large castings is accomplished faster with the stationary 250 KV Constant Potential Unit.

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Now – with transportable units, stationary units up to 250 KV capacity, production line units and versatile fluoroscopic units including image amplification, Westinghouse solves your most difficult internal inspection problems.

If you feel that our staff of Industrial X-ray Engineers can assist you in any way, please write: Westinghouse Electric Corporation, X-ray Department, 2519 Wilkens Avenue, Baltimore 3, Maryland.

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X-RAY DEPARTMENT

Westinghouse Electric Corporation

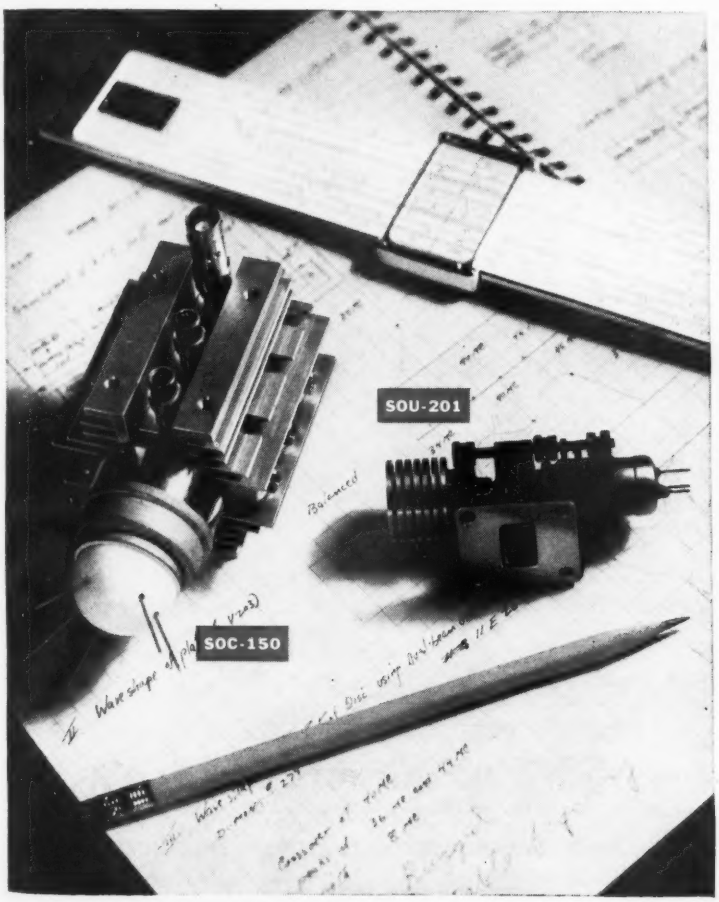
2519 Wilkens Avenue, Baltimore 3, Maryland

J-08333

New Sperry transponder tubes for missiles and jets offer high signal stability

High-output SOC-150 and SOU-201 klystron oscillators resist shock, vibration, wide temperature swings

NOW AVAILABLE, these new Sperry klystron oscillators were specially designed to withstand the severe environmental stresses generated in high-speed jet aircraft and guided missiles. Both types feature high signal stability and output power. Yet dimensions are held to the compact size required in radar guidance systems designed for the newest missiles. Each individual tube is tested to the extremes of shock and vibration encountered in these applications. Write for application data on the SOC-150 and SOU-201 as well as similar tubes for other frequency bands.



SOC-150

Two-resonator oscillator easily frequency modulated over a frequency range centered as specified by the customer. Symmetrical mode tuned for operation at high ambient and wide temperature extremes.

Frequency	C-band
Beam voltage	1000
Beam current	150 ma
Heater voltage	6.3 v
Heater current	.8 a
Power output	10 w
Weight	18 oz
Dimensions	4 3/4" x 4 1/16" x 4"

SOU-201

Two-resonator oscillator of block construction with internal feedback for ruggedness and fast warmup. Short tuning struts. Built to comply with MIL5272A. Tuned by varying resonator gap capacity through semi-flexible diaphragm.

Frequency	13.5 ± 0.1 kmc
Beam voltage	1600
Beam current	128 ma
Heater voltage	6.3 v
Heater current	1.5 a
Power output	15 w
Weight	8 oz
Dimensions	3 1/2" x 1 3/8" x 1 3/8"

ELECTRONIC TUBE DIVISION

SPERRY GYROSCOPE COMPANY

Great Neck, New York

DIVISION OF SPERRY RAND CORPORATION

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SEATTLE • SAN FRANCISCO. IN CANADA: SPERRY GYROSCOPE COMPANY OF CANADA, LTD., MONTREAL, QUEBEC

AGAIN...a new DC motor by

EEMCO

for another of our latest missiles

Unquestioned reliability under any condition of shock, acceleration and vibration is the prime requisite for all components in today's advanced missiles and rockets. A minor deficiency in but one, to any degree, can nullify completely the effectiveness of the weapon.

EEMCO Type D-927 DC motor is a component in one of our missiles that meets these rigid requirements. In fact, **EEMCO** motors and actuators are on the majority of the latest aerial weapons because of their unfailing performance.

The reason for such widespread recognition of **EEMCO** quality is that **EEMCO** has designed and manufactured custom motors and actuators for the aircraft industry for many years.

EEMCO is a specialist in this specialized field. It makes nothing else.

SPECIFICATIONS FOR TYPE D-927 DC MOTOR

Type: DC motor meeting Military Specifications MIL-8609
Speed: Continuous at 9900 rpm
Load: 0.5 HP
Terminal Voltage: 27 volts, 18 amps
Weight: 7.25 lbs. with 2-circuit noise filter for ungrounded system
Weight of Filter: 1 lb.

EEMCO ELECTRICAL ENGINEERING & MANUFACTURING CORP.

4612 West Jefferson Boulevard, Los Angeles 16, California—Telephone REpublic 3-0151

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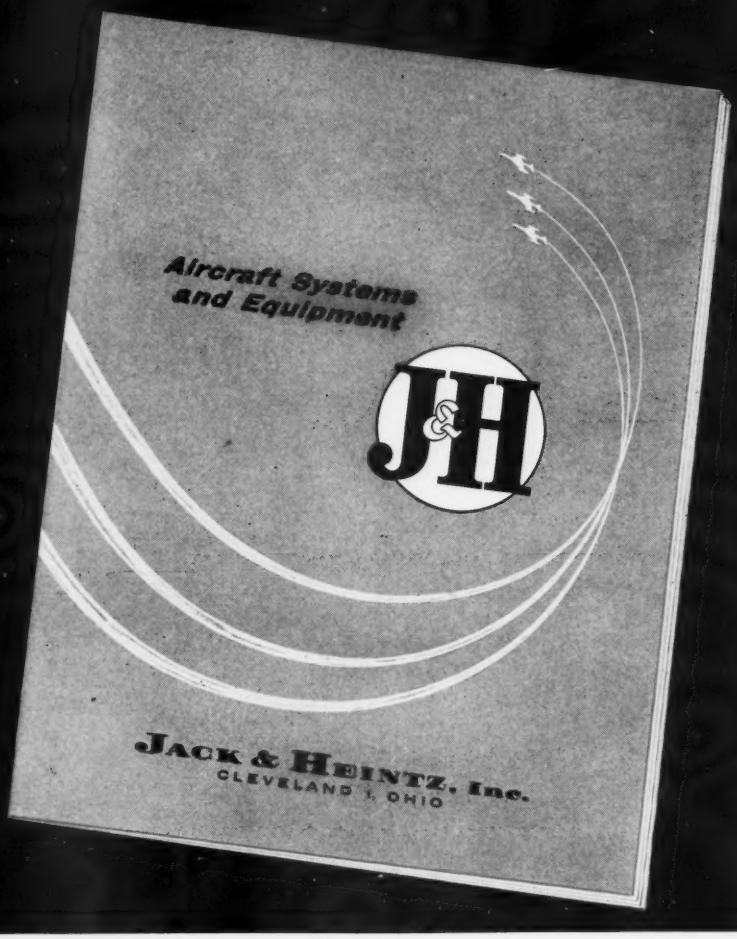

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Firm Name_____

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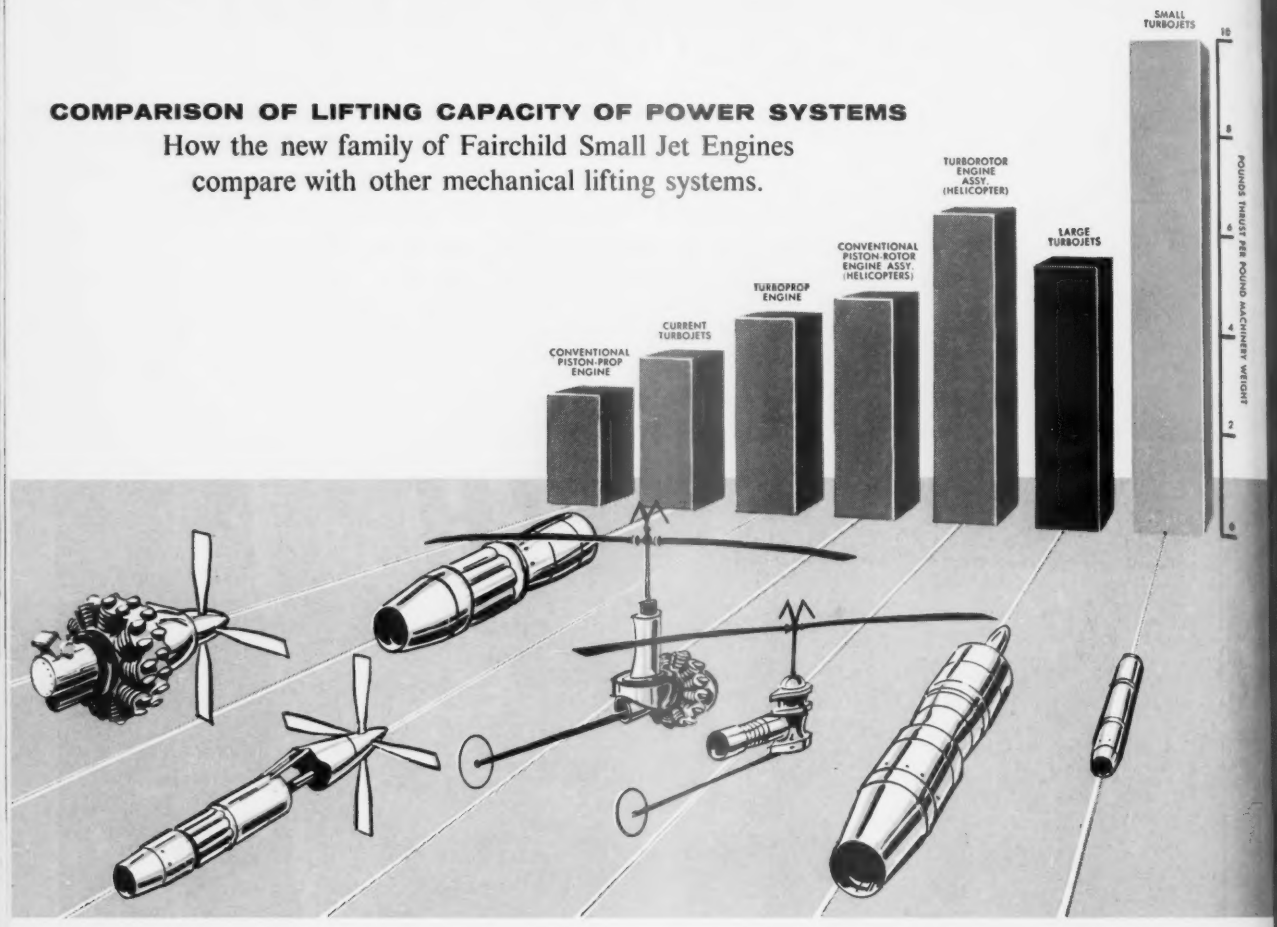
JACK & HEINTZ AIRCRAFT ELECTRIC EQUIPMENT

SMALL JET ENGINES... CHAMPION WEIGHT LIFTERS

COMPARISON OF LIFTING CAPACITY OF POWER SYSTEMS

How the new family of Fairchild Small Jet Engines compare with other mechanical lifting systems.



An entirely new family of aircraft will evolve from a new family of small lightweight jet engines now under development at the Fairchild Engine Division. These new powerplants will feature incredibly high thrusts and great lifting power . . . yet will be so light they can easily be carried by two men.

Highly compact, with low frontal areas, the small jet engines will deliver thrust/weight ratios starting at 8 to 1 with a long range potential of more than 10 to 1. They will be used in the high performance, lightweight trainers, interceptors, target drones, pilotless aircraft including missiles and intermediate class passenger and cargo jets of the nineteen sixties. They will also be used to power fighters and utility cargo craft, executive aircraft . . . and will make jet Short Take Off and Landing (STOL) and Vertical Take Off and Landing (VTOL) aircraft practical.

The small jet engine may be used singly, in pairs and in clusters. It provides multi-engine reliability in aircraft of a size now wholly dependent on a single engine. The small jet engine will produce greater versatility and utility in airplanes of tomorrow.

The extensive research facilities at Fairchild Engine Division have been designed solely to test performance of the small jet engine. They range from full scale, high altitude test chambers to supersonic research for component design. Fairchild Engine Division has spent a decade in the design, development and production of small, powerful jet engines.

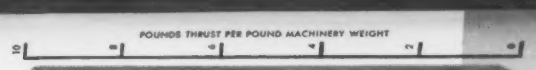
FAIRCHILD

ENGINE DIVISION

DEER PARK, LONG ISLAND, N. Y.

A DIVISION OF FAIRCHILD ENGINE AND AIRPLANE CORPORATION

..WHERE THE FUTURE IS MEASURED IN LIGHT-YEARS!


POUNDS THRUST PER POUND MACHINERY WEIGHT
10
8
6
4
2
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IAS News Notes

May 1957

ENLIGHTENMENT OF IAS MEMBERS has been and will continue to be a basic function of the Review. Beginning next month, the ever-widening interests of its readers will be served further in each issue by a new, information-packed editorial feature. This special section, to appear under the heading shown in reduced size at right, will contain engineering and scientific briefs from correspondents around the globe. The Editors will welcome all comments and contributions.

DATELINE world PROFESSIONAL NOTES AND REPORTS
Engineering and Scientific Briefs from Correspondents Around the Globe

* * * * *

LT. GEN. THOMAS S. POWER, USAF, ARDC Commander, will speak on "Air Force Research and Development in Space Technology" at the IAS National Summer Meeting banquet, June 19, in Los Angeles.

* * * * *

NATIONAL TELEMETERING CONFERENCE planners have scheduled eight technical sessions at El Paso's Hotel Cortez, May 27-29. Registration will be at the hotel on Sunday, May 26, from noon to 10 p.m. Sponsors are the IAS, ISA, and AIEE.

* * * * *

LT. (j.g.) FRANKLIN F. ECKHART, has been selected by the Institute to receive the 1957 Flight Test Engineering Fellowship. A Line Operations Officer, he will begin courses in flight test engineering at Princeton University this fall.

* * * * *

AN URGENT NEED for historical data and material in connection with the Naval Aviation Meeting has been broadcast by the San Diego Section. The appeal is for material relating to naval aviation history, with particular reference to early developments between 1910 and 1930. This material will be considered for inclusion with historical material to be on display during the meeting. Items are not to be sent directly unless and until specifically requested. All IAS individual and corporate members who have items are asked to get in touch with the Historical Committee, Naval Aviation Meeting, Institute of the Aeronautical Sciences, 3380 North Harbor Drive, San Diego, California.

* * * * *

RECENT DEATHS: Air Vice-Marshall Ernest W. Stedman, RCAF (Ret.) (F); George L. Shue (AF); Joseph H. Reisner (M); Charles E. Craven (M). Details will be recorded in the June Necrology Section.

NATIONAL MEETINGS CALENDAR

6/17-20	National Summer Meeting, Biltmore Hotel, Los Angeles, Calif.
8/5-10	Naval Aviation Meeting, U. S. Grant Hotel, San Diego, California.
9/1-15	Sixth Anglo-American Aeronautical Conference, Royal Aeronautical Society and IAS, London and Folkestone, Great Britain.
10/21-22	Canadian Aeronautical Institute-IAS Meeting, Montreal, Canada.
11/7-8	Weapons System Management Meeting, Statler-Hilton Hotel, Dallas, Texas.
12/7	Wright Brothers Lecture, Washington, D. C.
1/27-31	Twenty-Sixth Annual Meeting, Sheraton-Astor Hotel, New York.

JOINT MEETINGS CALENDAR

5/13-15	IRE National Conference on Aeronautical Electronics, Dayton, Ohio. IAS Session on Cooling, sponsored by Dayton Section.
5/27-29	National Telemetering Conference, Hotel Cortez, El Paso, Texas. Sponsored by IAS, ISA, and AIEE.
6/19-21	1957 Heat Transfer and Fluid Mechanics Institute, California Institute of Technology, Pasadena, Calif. Cosponsored by IAS.

SECTION MEETINGS CALENDAR

May 8	Texas Section: Specialist Meeting, Arlington State College, Engineering Auditorium, 8 p.m. "Helicopter Autopilots and Flight Simulators" by G. Matheny.
May 9	San Diego Section: Dinner Meeting, Admiral Kidd Officers Club, 6:30 p.m. Field trip (classified) through Navy's Sonar School.
May 14	Indianapolis Section: Annual Business Meeting, election of officers, Highland Country Club. Social period 6:30, dinner 7, and meeting at 8 p.m.
May 14	Los Angeles Section: Specialist Meeting, IAS Building, 8 p.m. "Acoustical and Vibration Environmental Investigations of the Snark SM-62 Missile" by Douglas T. Egbert.
May 16	San Francisco Section: Dinner Meeting, Ramor Oaks, Atherton, 7 p.m. "Hydrocarbon Fuels in the Atomic Age" by R. O. Bolt.
May 20	Boston Section: Annual Dinner Meeting, Thompson Club, Nahant, 6 p.m. "Guided Missiles vs. Airplanes" by Capt. G. Merrill, USN.
May 24	San Diego Section: Family Night, IAS Building.

REGIONAL STUDENT CONFERENCES

May 3-4	Middle Atlantic: University of Virginia, Charlottesville, Virginia.
May 7	Detroit: Wayne State University. Sponsored by Detroit Section.

IAS News

A Record of People and Events of Interest to Institute Members

Sixth Anglo-American Aeronautical Conference

British and Americans to Present 16 Papers at Folkestone, Diversified Program Planned

The tentative program of technical sessions for the Sixth Anglo-American Aeronautical Conference, September 1–15, lists eight British and eight American papers. They will be presented at Folkestone, Great Britain, from September 9–12.

British papers scheduled are:

"The Electrical Control of Power Plants" by G. M. Sturrock, Ultra Electric Ltd.

"Some Aspects of Kinetic Heating" by J. Taylor, Royal Aircraft Establishment, Farnborough.

"The Use of High Temperature Non-Metallic Materials" by W. J. Strand and W. A. Baker, Bristol Aircraft Ltd.

"Safety in Relation to Structural Damage" by A. E. Russel, Bristol Aircraft Ltd.

"The Presentation of Information by Aircraft Instruments" by A. Stratton, RAE, Farnborough.

"Future Aerodynamic Shapes" by P. A. Hufton, RAE, Farnborough.

"Small Nuclear Power Units" by J. V. Dunworth, Atomic Energy Research Establishment, Harwell.

"The Human Pilot as an Aircraft Operator" by Squadron Leader T. C. D. Whiteside, Institute of Aviation Medicine, Farnborough.

The schedule of American papers includes:

"NACA Research on VTOL and STOL Airplanes" by Marion O. McKinney, Jr., Langley Aeronautical Laboratory, NACA.

"Aerodynamic Effects of Boundary-Layer Unsteadiness" by Franklin K. Moore, Head, Aerodynamic Research Department, Cornell Aeronautical Laboratory, Inc.

"The Role of Experimental Hyperballistics in the Development of Future Airplanes and Missiles" by Herman H. Kurzweg, Associate Director, Aeroballistic Research, U.S. Naval Ordnance Laboratory.

"Increased Lift Through Boundary-Layer Control" by Charles W. Harper, Ames Aeronautical Laboratory, NACA.

"Ten Years' Experience With Titanium" by Leo A. Schapiro and Emerson LaBombard, Douglas Aircraft Company, Inc.

"Blast Loads on Aircraft Structures" by R. L. Bisplinghoff and E. A. Witmer, Massachusetts Institute of Technology.

"Control of Supersonic Propulsion Systems" by Bruce T. Lundin, Lewis Flight Propulsion Laboratory, NACA.

"An Appraisal of Aeroelasticity in Design, With Special Reference to Dynamic Aeroelastic Stability" by Martin Goland, Southwest Research Institute.

Travel Arrangements

All IAS members are invited to attend the Anglo-American Conference. However, the Institute can handle travel arrangements and plant visits for only those members who are United States citizens residing in the United States. All others should make arrangements directly with The Royal Aeronautical Society.

Members of the Institute may be designated "Official Delegates" by writing to R. R. Dexter, IAS Secretary, for application forms. These forms will provide information on air or sea transportation through the facilities of Travel Center of Manhasset, Inc., class of travel, tentative departure and arrival schedules, rates, and ticketing. Information is also given on hotel accommodations, including a list of London hotels, approximate daily rates, and a form for making reservations. Accommodations at Folkestone have been arranged.

Post conference tours and independent travel may also be arranged.

Sir George Edwards, Managing Director, Vickers-Armstrongs (Aircraft) Ltd., 1957 President, RAeS.

Members may make reservations for tours but must supply details if independent travel is desired.

Miscellaneous information on car rental or purchase, travel insurance, baggage insurance, and an international charge service will be supplied.

United States citizens are required to have a valid passport and smallpox vaccination certificate which they must obtain themselves. Information on this is available through travel agencies or international air lines.

Conference Blueprint

The proposed program for the Conference calls for registration to take place from August 31 to September 1. Open days have been scheduled on the Saturdays, September 7 and 14. Departure from London to Folkestone has been scheduled for Sunday, September 8. Return to London is scheduled for Friday, September 13.

The program schedule includes:

A visit to Fairey and Handley-Page plants; or to London Airport and British European Airways Engineering Base; and Society of British Aircraft Constructors Dinner; on September 2.

SBAC Farnborough Air Show on September 3 and 4.

Varied Program Planned for IAS National Summer Meeting

Thirteen Sessions, Panel Discussions Scheduled for June 17–20 at Biltmore Hotel, Los Angeles

A PROGRAM marked by almost a 50 per cent increase in the number of technical sessions has been planned for the Institute's National Summer Meeting, June 17–20, at the Biltmore Hotel, Los Angeles.

Committees set up to plan the program have announced a wide variety of subjects. For the first time, sessions will be held simultaneously. Thirteen sessions, an informal panel discussion by three aviation pioneers, a banquet, a luncheon, and a classified field trip have been scheduled.

Sessions will cover Aerodynamics, Technical Requirements Planning, Propulsion, Systems Concept, Structures, Electronics in Aviation, Environmental Planning, The Engineer in Management, Flight Testing, Guidance Systems, Business Aircraft, Control Systems, and Development of the F-104 (classified).

"Aeronautical Engineering Trends: In the Past and in the Future," will be discussed by Donald W. Douglas, President of Douglas Aircraft Company, Inc.; J. H. Kindelberger, Chairman of the Board, North American Aviation, Inc.; and Robert E. Gross, President and Chairman of the Board, Lockheed Aircraft Corporation. General Ira Eaker, USAF (Ret.), will be Panel Moderator.

Guest speaker at the banquet will be Lt. Gen. Thomas S. Power, USAF, ARDC Commander. He will speak on "Air Force Research and Development in Space Technology."

Clark B. Millikan, Director of the Guggenheim Aeronautical Laboratory and Southern California Cooperative Wind Tunnel, California Institute of Technology, will be the luncheon speaker.

A complete program will be in the mail to members this month. The session line-up to date is as follows:

Monday, June 17

Aerodynamics (9:30 a.m.), "Design Considerations in the Application of Boundary Layer Control and Jet Flaps to Transport Aircraft" by William T. Hamilton, Aerodynamics Staff Engineer, Boeing Airplane Co.; "The Research Airplane Program—Past, Present, and Future" by W. C. Williams, NACA High Speed Flight Station, Edwards AFB, Calif.; "The Prospects for Magneto Aerodynamics" by W. R. Sears, Director, Cornell University Graduate School of Aeronautical Engineering; and Edwin L. Resler, Associate Professor, Aeronautical Engineering, Cornell.

Technical Requirements Planning (9:30 a.m.), papers and speakers to be announced.

Propulsion (1:30 p.m., classified), panel discussion.

Systems Concept (1:30 p.m.), panel discussion.

"Aeronautical Engineering Trends: In the Past and in the Future" (8 p.m.), panel discussion.

Tuesday, June 18

Structures (9 a.m.), "Thermal Creep Design Criteria" by Robert Goldin, Structural Design Engineer, Bell Aircraft Corporation; "Panel Flutter in a Supersonic Flow" by Y. C. Fung, Associate Professor of Aeronautics, California Institute of Technology; "The Selection of Structural Materials for Supersonic Flight" by Donald D. Cox, Boeing Airplane Co., Seattle.

Electronics in Aviation (9 a.m.), "Fundamentals of Collision Warning" by Emory Lakatos, The Ramo-Wooldridge Corporation, Control Systems Division; "Dynamics of Aircraft Instrumentation" by Victor Azgapetian, Advance Engineer, Servomechanisms, Inc., Advance Engineering Section.

Luncheon (12 noon to 2:30 p.m.).

Environmental Testing (2:30 p.m.), "Environmental Simulation: A Tool for the Contemporary Engineer" by H. John Cail, J. B. Gill Division of Paul Hardeman, Inc., Los Angeles; "Environmental Testing of Avionic Equipment" by Robert H. Douglass, Jr., Servomechanisms, Inc.; "New Sonic Test Environments and Facilities" by Ken Jackman, Convair Division, General Dynamics Corporation.

The Engineer in Management (2:30 p.m.), panel discussion.

Development of the F-104 (8 p.m., classified) by C. L. Johnson, Vice-President, Engineering and Research, Lockheed Aircraft Corporation.

Wednesday, June 19

Flight Testing (9 a.m.), "Flight Testing of Missiles" by Milton Kuska, Northrop Aircraft, Inc.; "Flight Testing of Supersonic Aircraft" by Laverne Howland, Lockheed Aircraft Corporation, Burbank; "Flight Testing VTO Aircraft" by Charles E. Myers, Jr., Convair Division, General Dynamics Corporation.

Guidance Systems (9 a.m.), "Principles of Self-Contained Navigation" by H. H. Bailey, Sperry Rand Corporation; "Inertial System Aids" by Frederick Stevens, Northrop Aircraft, Inc.; "Stable Platforms in High Performance Aircraft" by R. H. Cannon, North American Aviation, Inc., Autonetics Division.

Business Aircraft (1:30 p.m.), panel discussion.

Control Systems (1:30 p.m.), "Optimum Response Characteristics of Airplane Control Systems" by L. F. Kurrasch, Douglas Aircraft Company, Inc.; El Segundo Division; "The Effect of Vortex and Shock Expansion Fields on Pitch and Yaw In stability of Supersonic Airplanes" by Jack N. Nielsen and

Welko E. Gasich
Chairman, Los Angeles Section

Donald A. Justice
Meeting Chairman

Session Chairmen

Harold Luskin

Carlos C. Wood

E. J. Specht

Trevor Gardner

G. N. Mangurian

Ralph Redemske

George E. Kaattari, Ames Aeronautical Laboratory, NACA; "Electric Control Stick Development Program" by R. A. Westerwick, Convair Division.

Banquet (7 p.m.), Mundy I. Peale, IAS President and President of Republic Aviation Corporation, will be Toastmaster.

Thursday, June 20

Field Trip (classified), inspection of Palmdale production flight-test facility and F-104 demonstration.

Management Engineers

One of the highlights of the meeting will be the panel discussion on "The Engineer in Management," at 2:30 p.m. Tuesday. Participants will include L. A. Hyland, Vice-President and General Manager of Hughes Aircraft Company; George S. Trimble, Jr., Vice-President—Engineering, The Glenn L. Martin Company; Myles L. Mace, Vice-President, Litton Industries, Inc.; and Demetrius Gerdan, Director of Engineering, Aircraft Engine Operations, Allison Division of General Motors Corporation.

These speakers will discuss such question as: What is the management function; to what extent does an engineer's training prepare him for management; what should be the engineer's choice, technical specialization or management, and what factors influence his decision; what should an engineer do to improve his management skills and knowledge; and what should industrial management do to help an engineer improve his management skills?

Flying Businessmen

The Business Aircraft Panel Discussion will center on the businessman's aircraft of the future. Speakers will discuss such things as "driving" rather than "flying" an airplane, approaches to automatic flight, future availability of lightweight jet engines, prop-jet versus turbojet, increased speed and versatility, rapid transport needs of the business concerns' normal working staff, economic justification of aircraft for the small businessman, and other current problems.

The schedule of speakers includes: Major. Gen. J. W. Sessums, Jr., USAF, Vice Comdr., Air Research and Development Command; Rufus Amis, President, Aero Design and Engineering Co.; Ralph M. Harman, Chief Engineer, Business Transport Aircraft, The Cessna Aircraft Co.; August Raspet, Head, Aerophysics Department, Mississippi State College; Edgar Schmued, Vice-President and Chief of Engineering, Northrop Aircraft, Inc.; William K. Lawton, Executive Director, National Business Aircraft Association; and Win H. Arata, Jr., Chief Operations Engineer, Fairchild Engine and Aircraft Corporation.

Program Planners

Don Justice of The Ramo-Wooldridge Corporation is Chairman of the National Summer Meeting. The following is a list of subcommittee chairmen who handled various details and arrangements:

Jerry F. L. Aldrich, Douglas Aircraft Company, Inc., El Segundo Division; David Badger, Northrop Aircraft, Inc.; Ben Cagle, Southern California Cooperative Wind Tunnel; C. R. Cantrell, Lockheed Aircraft Corporation, Burbank; Stanford Church, Douglas, Long Beach Division; S. D. Fasken, Marquardt Aircraft Company; H. S. Hansen, Servomechanisms, Inc.; Reuben G. Klammer, Hughes Aircraft Company; L. E. Lundquist, Douglas, Santa Monica; S. W. Mikulka, General Electric Company; G. L. Rounds, Ramo-Wooldridge; J. L. Velasquez and J. R. McMaster, Lockheed, Burbank; and R. C. Whitaker, Marquardt.

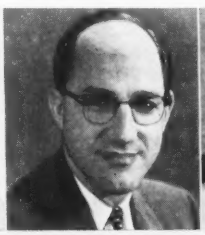
The list of session chairmen includes: Aerodynamics, Harold Luskin; Technical Requirements Planning, Carlos C. Wood; Propulsion, E. J. Specht; Systems Concept, Trevor Gardner; Structures, G. N. Mangurian; Electronics in Aviation, Ralph Redemske; Environmental Testing, W. L. Vandal; The Engineer in Management, J. L. Atwood; Flight Testing, George R. Mellinger; Guidance Systems, Robert M. Ashby; Business Aircraft, William P. Lear, Sr.; and Control Systems, Allen E. Puckett.

The field trip will be limited to 400 visitors. It will start with breakfast at 6:15 a.m. in the IAS Building. Busses will depart for Palmdale at 7 a.m.

W. L. Vandal

J. L. Atwood

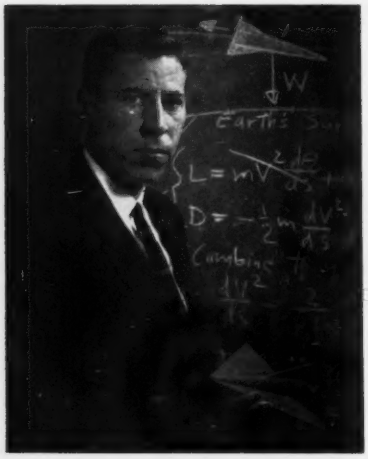
G. R. Mellinger



Robert M. Ashby

W. P. Lear, Sr.

Allen E. Puckett



Alfred J. Eggers, Jr. (AF), has been named to receive the Arthur S. Flemming Award for his work in the field of atmosphere re-entry, for original research accomplishments in problems of hypersonic flight, and for development of a hypersonic wind tunnel. Dr. Eggers is Chief, 10- by 14-in. Supersonic Wind Tunnel, NACA Ames Aeronautical Laboratory, Moffett Field, Calif. The Flemming Award is given annually to young men under 40 for outstanding Government work.

Systems Laboratories Corporation Is New IAS Corporate Member

Systems Laboratories Corporation, a Delaware corporation formed last year for research and development in space and airborne systems, has joined the Institute as a Corporate Member. Head office of the company is at 15016 Ventura Blvd., Sherman Oaks, Calif.

Counting consultants and part-time employees, the company had 56 employees as of February 1. SLC has on its professional staff scientists and engineers prominent in the fields of space, aeronautics, nucleonics, rocket propulsion, electronic and electromechanical sensors, processors and actuators, applied mathematics, and systems design.

The firm is performing early research and development to determine feasibility of well-integrated advanced systems. It also is concerned with the instrumentation of such systems after they have been manufactured by other organizations.

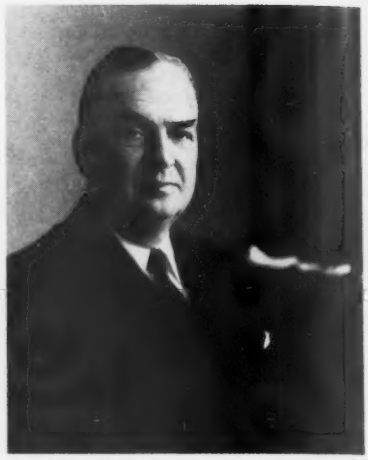
James D. Redding (AF), former Manager of Westinghouse Corporation's Headquarters Sales Department, Aviation Gas Turbine Division, has been appointed the division's General Manager of the Sales & Service Department. He had been Acting Manager in this post since January 1.

Chain Belt Company Division Joins IAS as New Corporate Member

The Shafer Bearing Division, Chain Belt Company, originator of "ConCaVex" aircraft bearings, is another new member in the Institute's Corporate Member fold. The firm is located at Downers Grove, Ill.

Shafer introduced the ConCaVex bearing in 1919. The design combined inherent operational efficiency of the ball type and the greater load capacity of the straight roller-type bearing.

Douglas Aircraft Company in 1938 became the company's first aircraft customer for these bearings. The first series were of the double row, self-aligning cylindrical design and are similar to those being supplied many aircraft manufacturers for installation on control surfaces, landing gears, and hydraulic actuating equipment. The first aircraft rod ends were developed for Lockheed in 1940 and are standard equipment in control systems of the latest commercial and military airplanes.



Claire L. Egtvedt (F), Chairman of Boeing Airplane Company, has been named the University of Washington's most distinguished alumnus for 1957.

Aeronautical advances in the last decade have necessitated extensive research in metallurgy and lubricants suitable for higher loadings and higher operating temperatures. Shafer engineers are working with aircraft manufacturers in the development and environmental testing of new bearing designs to satisfy these requirements.

NEWS OF MEMBERS

Members on the move . . . .

This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.

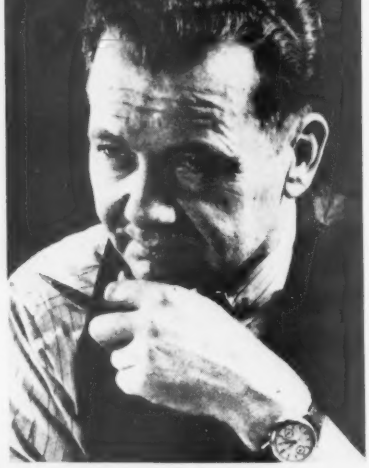
R. Harvey Anselm (M), Project Engineer, Missile Engineering Division, Beech Aircraft Corporation, has been transferred from the firm's main facility in Wichita, Kan., to its Boulder, Colo., engineering facility. Mr. Anselm is directing activities of the Missile Engineering Division at Boulder.

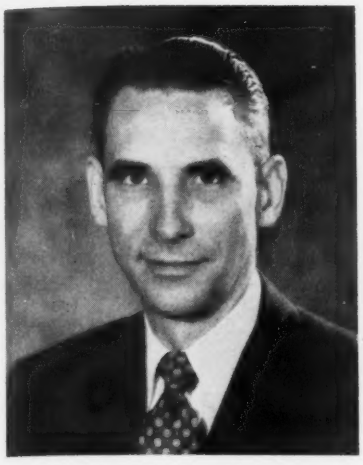
Irving Forsten (AF), former Chief, Analysis Branch, U.S. Naval Air Rocket Test Station Engineering Department, has been promoted to the position of Chief Engineer.

John W. Goslee (M), formerly Senior Service Engineer, Bendix Products Division, Bendix Aviation Corporation, has joined United Aircraft Corporation, Pratt & Whitney Aircraft Division. After a training period in West Hartford, Conn., he will be located on the West Coast.

George Kass (AF) has been assigned to the investigation and evaluation phase of a new project at Stratos Division, Fairchild Engine and Airplane Corporation, Bay Shore, L.I., as Assistant Senior Project Engineer. Until late last year, he was with East Coast Aeronautics, Inc.

Stephen J. Zand (F), Consulting Engineer, has been named to the Advisory Council of the Gannon College School of Engineering.





Earle W. Barry (A), has been appointed Vice-President in charge of sales of Trecker Aircraft Corporation, Royal Gull amphibians in Latin American countries. Formerly, he was a sales executive with Aviquipo, Inc.

Walter B. Brewer, Jr. (M), formerly Principal Engineer at Cornell Aeronautical Laboratory, Inc., has been promoted to Assistant Head, Weapon Systems Design Department.

William E. Crowell (M) has been promoted to Head of the Weapon Systems Design Department at Cornell Aeronautical Laboratory, Inc. He formerly was Assistant Department Head.

U. O. Lappi (M) has left Cornell Aeronautical Laboratory, Inc., where he was a research engineer to join the New York University College of Engineering Research Division as Engineering Scientist. He also will pursue a doctorate program at N.Y.U.

William F. Sauers (AF), former Management Consultant, Booz, Allen & Hamilton, has been appointed Operations Manager for the TM-61 Matador weapons system program at The Glenn L. Martin Company, Baltimore.

Necrology

Berthin Grottland

News of the death of Berthin Grottland (A), Thermodynamicist for Orenda Engines, Ltd., Malton, Ontario, Canada, has been received by the AERONAUTICAL ENGINEERING REVIEW. He was 38.

Mr. Grottland, a native of Norway, was a graduate of the University of Toronto. He also had attended the Oslo Technical School in Norway.

Bradley Jones

Bradley Jones (AF), a Founder Member of the Institute and pioneer in the development and testing of aircraft instruments, died March 8 in Good Samaritan Hospital, Cincinnati, 2 weeks after suffering an acute heart attack. Sixty-six when he died, he also was Head of the Aeronautical Engineering Department of the University of Cincinnati and Faculty Adviser for the IAS Student Branch there.

Professor Jones was founder of the cooperative program of aeronautical engineering at Cincinnati. Born in Boston, he was educated at Massachusetts Institute of Technology and Norwich University.

In the mid-twenties, Professor Jones was in charge of instrument testing at the Government experiment station at McCook Field, Dayton, Ohio. While there he and his colleagues gained national attention for nonstop flights from Dayton to Boston and Dayton to Pensacola, Fla. They flew above the clouds out of sight of all landmarks commonly used by pilots as part of a program to test an earth-indicator compass and flight indicator.

He joined the faculty at Cincinnati in 1929, after 7 years at McCook Field. He was Associate Editor of *U.S. Air Services* and wrote books on flying including *Dynamics* and *Aerodynamics for Pilots*.

Leo Abbott Leissler

Word of the death on January 18 of Pfc. Leo Abbott Leissler (A), an Inspector at the Army Ordnance Depot, Fontenet, France, has been received. He was 27.

Private Leissler had been an Engineering Aide at the National Advisory Committee for Aeronautics, Lewis Flight Propulsion Laboratory, Cleveland, before he entered the Army. His job was to assist project engineers in the preparation, execution, and reduction of research projects.

He was a graduate of Purdue University, Class of '51, and also attended Case Institute of Technology. He joined NACA shortly after his graduation.

F. Glen Nesbitt

News of the death on February 24 of F. Glen Nesbitt (M), 51, has been received.

Mr. Nesbitt, Assistant Sales Manager for the Aeronautical Equipment Division of Sperry Gyroscope Company, was born in Vincennes, Ind., and was a graduate of Purdue University.

From 1928 to 1944 he served in progressive grades of aeronautical engineering with the Army Air Corps at Wright Field, Dayton, Ohio. During this time he was stationed in the Instrument and Navigation Department of the Engineering Division. He was a project engineer on various instruments including altimeters, gyroscopic instruments, and automatic pilots.

Mr. Nesbitt was Chief of the Gyro Instrument Unit from the time it was formed until he resigned in 1944. He then joined Sperry as Aeronautical Application Engineer and contributed to the development and acceptance of the Sperry Gyrosyn Compass, the model A-12 Gyropilot, and the Sperry Zero Reader.

Mr. Nesbitt served on the official timing staff of the National Air Races, Cleveland, for many years and was a member of the National Aeronautic Association.

CORPORATE MEMBER NEWS

• **Aerojet-General Corporation . . .** Structural Plastics Department exhibited products made by filament winding at the Pacific Coast Plastics Exposition in Los Angeles.

• **Allison Division, General Motors Corporation,** reports only 4 per cent hp. loss due to ice on Aeroproducts three-bladed propellers. As a result of this experiment, Allison engineers said deicing equipment for propellers may become a thing of the past. Their findings will be turned over to the CAA, air lines, and air-frame manufacturers for additional review.

• **American Airlines, Inc.,** has announced that the Turner Construction Company of New York will begin construction of a

(*Continued on page 118*)

Guest Editorial

Mundy I. Peale

President

Republic Aviation Corporation

Electronics in Aviation

Draw two lines on a graph, one representing the number of command functions a fighter pilot is capable of performing, the other representing the number of these functions that electronic devices can perform.

If you start the graph just before World War II, you find the human line high on the scale, the electronic line low. The fighter pilot performed almost all command functions, and electronics stuck pretty closely to running the instruments.

But during World War II the human line began to move downward. Electronics began to take over an increasing number of combat and navigational chores, chores which the pilot was either incapable of performing or which he could not perform as efficiently as with electronic aids.

Thus the two lines began moving in a converging pattern, and each has continued in the same direction since. Inevitably they will meet. When they do, the missile will be merged with the piloted craft, and out of this wedding will come a weapons system unlike any we now have.

Today we have arrived at a point where air-to-air and air-to-surface missiles working electronically for the pilot are making real strides in this direction, although the day still is far distant when the pilot will become dispensable in all offensive and defensive weapons.

Too much general confusion exists over the defense question of missile vs. manned aircraft today. The question must always be considered in terms of the military missions required to preserve world peace.

Military missions must be considered in a great number and varied types of categories with respect to the target complexes against which the weapons systems operate. Unmanned aircraft exist today or will appear shortly which have sufficient accuracy to destroy some military targets with available warheads. Only manned aircraft, however, operating with the help of the most advanced electronic aids now envisioned can be used with sufficient accuracy to destroy other targets. Thus the electronic developments have not only made the missile possible but have also greatly increased the usefulness and extended the life of the manned aircraft to the point where it appears that both missiles and manned aircraft will coexist for the next decade or more. I use the word "decade" reservedly because the electronic developments also will increase the effectiveness of countermeasures. The degree to which countermeasure development is accomplished will have much to do with deferring the time in which we may expect safely to eliminate the judgment of the pilot.

If we had a static set of conditions to work with—that is, if performance requirements could remain the same over the next few years—we could pinpoint more precisely our future chronology. We could predict with some accuracy when the devices of the electronics engineers would reach a point of capability equal in all respects to that of the human pilot.

But such, of course, is not the case. What is accomplished in the fields of aerodynamics, of ballistics, of chemistry, and of metallurgy—to name just a few—will bear directly on how much additional must be done in the field of electronics before we have the age of unmanned military aircraft.

So perhaps this is the time to look at a couple of the certainties in the future of avionics rather than speculate on the imponderables.

First, the most important single factor in deciding how rapidly we move toward widespread use of unmanned aircraft will be the ability of the electronics industry to pack more electronic performance into less space and weight.

This would be necessary even if the aim were only to accomplish the jobs that are *now* required of the pilot-plane combination. But when you add to these present jobs the inevitable new ones to be added over the years, you immediately see a proliferation of equipment so rapid as to make absolutely essential the further microminiaturizing of this equipment while at the same time endowing it with the ability to perform an increasing number of jobs.

Electronic countermeasure equipment is just one example of this inevitable proliferation; and under this one heading are included air-borne jamming systems, ground passive detection equipment, and distributed area jamming systems.

Second, and most obviously, all this added complexity is going to be reflected in added cost per plane. The comparison of past with present plane costs is already familiar, but I think possibly it bears repetition here while we are talking about future electronic complexity. A World War II fighter had three electronic/communication systems and a flyaway cost of about $50,000. A 1955 jet fighter has had its electronic communication systems tripled in number (to nine) and its price increased by more than seven times (to $350,000).

Electronics, in other words, will not come cheap. And here, I think, we can add another predictable for the interim period between now and the pilotless plane: There will be an increasingly difficult time for everybody—from Congressmen to military procurement officers to aircraft industry manufacturers—whose job it is to provide adequate air defense within the bounds of prudent fiscal policy.

These facts should be obvious. But it seems to me that even some of us in the aircraft industry have tended to overlook them in our infatuation with the wonders of electronics. Certainly, we, more than anyone else, should see clearly the difficulties that lie ahead in creating the unmanned aircraft. Yet too many of us, reacting almost like Sunday supplement readers, have overlooked these difficulties and have assumed that the electronics miracle workers can create anything.

In the long run, they undoubtedly will, I think, require more time than is generally assumed. And in the meantime we in the aircraft industry must be prepared to fight the battles of growing complexity and costs.

ELECTRONICS IN AVIATION

William J. Tull*
General Precision Laboratory

Doppler Navigation†

Description of a new sensing and measuring device for ground speed and drift angle utilizing the Doppler effect, which is now in operational use on many types of aircraft.

It is the purpose of this paper to describe a new technique for measuring ground speed and drift angle without celestial or terrestial assistance. It is now possible to do this with a high degree of accuracy, in all kinds of weather, over both land and water, completely automatically, and with equipment of practical size and weight. The basis for this development is a new sensing element, never before available for air-borne use.

The technique which makes possible the sensing and measurement of ground speed and drift angle utilizes what is commonly referred to as the Doppler effect. The Doppler phenomenon itself has, of course, been well known for many years. The equipment which utilizes this phenomenon at microwave frequencies and which comprises the necessary instrumentation for its measurement is commonly referred to as Doppler radar equipment, which is now available as a practical and producible device for use on board all types of aircraft.

Regrettably, current security restrictions preclude a detailed outline of the system, but to the extent possible I wish to illustrate briefly how General Precision Laboratory devices measure the ground speed and drift angle of an air vehicle.

Let us examine Fig. 1. On the left we have a stationary transmitter—receiver A. The transmitter is emitting a signal at a frequency f_T. The signal is reflected from the truck B back to the receiver A. Since the truck is moving with a velocity V, there will be a Doppler shift in the frequency of the reflected signal. The equation relating the several quantities involved is shown below. This equation is an expression for the difference in frequency between the signal transmitted and the signal received at location A. This difference frequency Δf is

$$\Delta f = (2V/c)f_T$$

The quantity c is the velocity of propagation of the electromagnetic signal.

In Fig. 2, the transmitter receiver A is now located in an aircraft flying over the ground. The transmitter is sending out a beam of energy from the aircraft to the ground. The beam is transmitted at an angle γ from the direction of the aircraft velocity vector V. The equation relating the several quantities in this illustration below. The equation for the difference frequency Δf is, in this case,

$$\Delta f = 2(V/c)f_T \cos \gamma$$

It is evident from this equation that Δf is a measure of the velocity V since the other quantities occurring in the right-hand member of the equation are known.

It should be noticed that in the above equation all energy reflected or back-scattered from the ground at the angle γ undergoes the same Doppler frequency

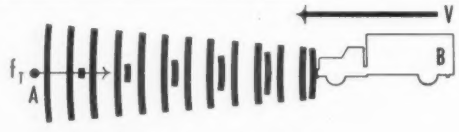


Fig. 1. $\Delta f = (2V/c)f_T$.

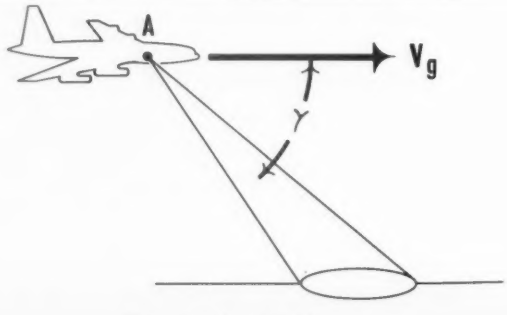


Fig. 2. $\Delta f = (2V/c)f_T \cos \gamma$.

† A condensation of the paper of the same title presented at the Self-Contained Air Navigation Systems Session, 25th Annual Meeting, IAS, N.Y., Jan. 28–31, 1957. Complete paper available as Preprint No. 681 from IAS Preprint Department.

* Vice-President and Director, Avionic Sales Division; Associate Director, Avionic Engineering Division.

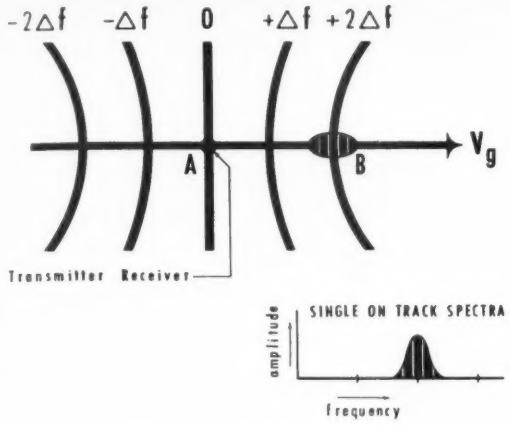


FIG. 3. $\Delta f = (2Vf_T/c) \cos \gamma$.

shift, Δf. Now let us draw the intersections with the ground of families of beams having constant γ angles. These intersections are hyperbolas, assuming a plane earth. These hyperbolas are conveniently thought of as contours of equal Doppler frequency shift.

Now let us consider Fig. 3. Here we are observers looking straight down from above on the air-borne transmitter A. The transmitter is traveling in the direction indicated by the velocity vector V_g. In the center we see the constant frequency contour for a γ angle of 90°. This is a zero Doppler frequency contour because in this case there is no relative velocity between the transmitter A and the ground—that is, for $\gamma = 90°$, the frequency shift is $\Delta f = 0$. The other contour lines on the illustration are for values of γ of magnitude less than 90°. The lines ahead of the transmitter represent the loci of echo sources having an increased frequency over those transmitted—that is, there is a closing velocity between the transmitter and the ground ahead. The contours behind the transmitter correspond to echo sources having decreased frequency from those transmitted. The transmitter has a velocity of recession from all elements of the ground behind the aircraft. Obviously, the smaller the angle gamma, the further ahead (or behind) the beam intersects the ground. Correspondingly, the smaller the value of gamma, the greater the value of Δf, the Doppler frequency shift.

Now let us project a small pencil beam from the transmitter at A to the ground at B. The energy is essentially confined inside the ellipse at B. It is evident that the signals within the beam B scattered from the ground nearest the transmitter are characterized by a larger gamma angle and a lower Doppler frequency shift than those further out. This is illustrated in the spectral power density plot in the lower right-hand corner of the Figure.

As we now go to Fig. 4, you will see that we once again have plotted the same constant frequency hyperbolae. However, in this case we have transmitted two beams of energy in two different directions. It can be seen from an examination of this Figure that, if one beam of energy is confined to the region L, the corresponding return signal has a spectrum as shown in the diagram at the bottom of the Figure. Similarly, one can picture the spectrum corresponding to the energy from region R. Let us now maintain the angle θ between the L and R regions constant, while the whole beam-forming assembly is rotated about a vertical axis. The frequencies associated with the beams L and R will change accordingly. In Fig. 5, we see what the situation would be when the beam assembly has been rotated until the frequencies from L and R are equal. In this situation it is obvious that the bisector of the angle θ lies in the direction of the velocity vector V_g.

In brief, then, by the measurement of the frequency Δf we can determine the ground speed of the aircraft, and by servoing a two-beam antenna system until equal Doppler frequencies are received from each we can measure drift angle. It is also possible to determine drift angle with a fixed two-beam system by measuring the Doppler frequency shift associated with each antenna beam. In this case, the drift angle must be calculated from the data rather than coming directly from a null measurement.

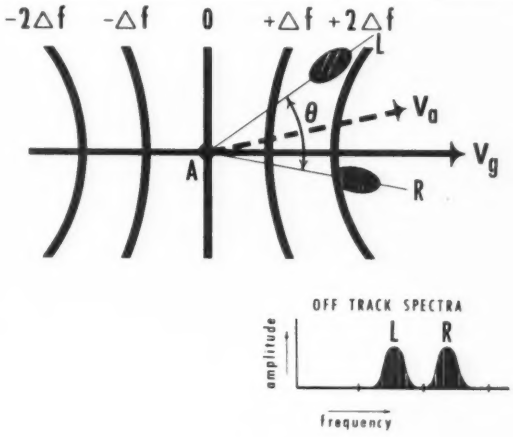


FIG. 4.

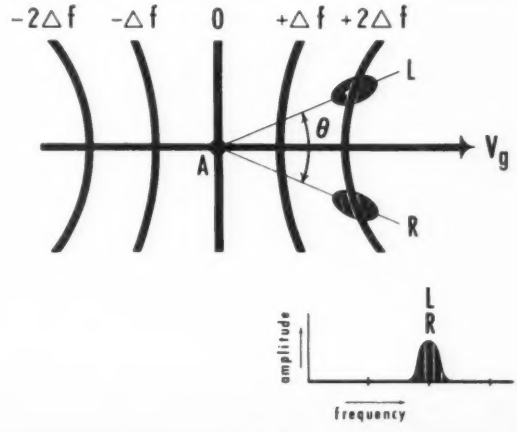


FIG. 5.

It is suggested by the above discussion that there are many ways of measuring the desired quantities and that there are many pros and cons with respect to various proposed instrumentation. Of course, any individual or group interested in using Doppler radar equipment must obtain a satisfactory answer as to the merits of each of the several ways of performing the measurements. Unfortunately, such detail consideration is beyond the scope of this paper and cannot be discussed because of military security. Therefore, it is recommended that those who are faced with a problem of deciding between any one of the several techniques obtain clearance and secure the information needed to assist in making a choice.

Thus far we have limited our discussion to the basic sensing element of an autonavigator system—namely, the Doppler radar drift angle and ground speed measurement equipment. If these measurements can be made, it is apparent that the information can be combined with heading information to provide continuous dead reckoning, thus presenting a continuous display of position in any desired coordinate system. For those of you not familiar with this process, it is shown in Fig. 6. The process is as follows:

(1) Drift angle is added to true heading giving true ground track direction.

(2) Ground speed is resolved about this ground track angle giving north-south and east-west components of velocity. These components are $V_g \sin \theta_T$ and $V_g \cos \theta_T$.

(3) By integrating the component velocities the distance traveled in both the north-south and the east-west directions can be computed. This provides data on position.

(4) By multiplying the east-west data by the secant of the north-south data (latitude), the east-west grid data becomes longitude.

If the above process were carried out continuously, the computer would determine position continuously relative to the point of departure. If the point of departure were known and the relative position were continuously added to it, present position would be continuously known.

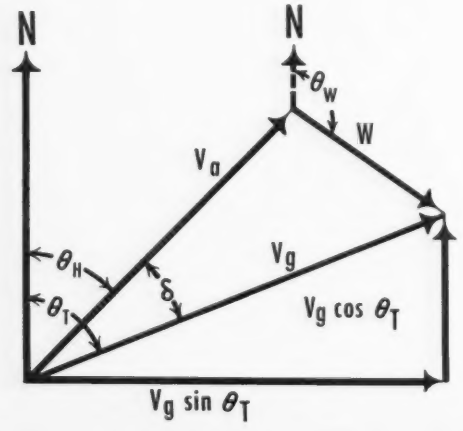


FIG. 6.

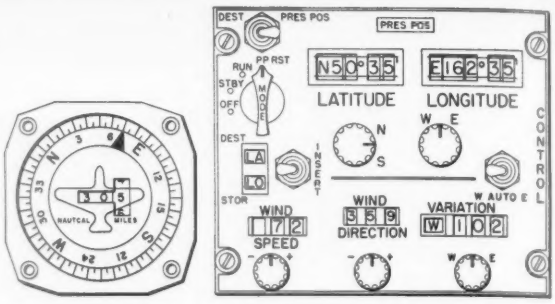


FIG. 7. AN/ASN-7 indicator and control panel.

At the present time, many dead reckoning computers are in existence which can, in theory at least, accommodate Doppler input data. In actual fact, only a few of these computers have been designed to accept this data. One such computer is the AN/ASN-7, designed and built by the Ford Instrument Company for the Air Force. Interconnection of a Doppler radar with this computer provides latitude and longitude of present position and course and distance to each of several desired destinations. A picture of the indicator and control panel of an ASN-7 is shown in Fig. 7. The ASN-7 is operated as follows:

(1) With switch labeled Dest-Pres Pos in the Pres Pos position, insert coordinates of point of departure.

(2) With above switch in Dest position, slew counters to desired destination #1. LA and LO flags will appear, indicating data stored.

(3) Press the insert switch until both the LA and LO destination insert flags disappear. This inserts destination #1 into the computer where it is used for course and distance to destination calculations.

(4) With the switch labeled Dest-Pres Pos in the Dest position and the insert switch in the storage position, slew counters to desired destination #2, causing LO and LA flags to appear indicating data stored.

(5) Return Dest-Pres Pos switch to Pres Pos position and fly to destination #1 reading course, distance to go, and present position from appropriate indicators.

(6) When destination #1 is reached, push insert switch until LA and LO flags disappear, indicating that destination # 2 is inserted.

(7) Fly to destination #2 the same as #1 and set up destination #3 the same as #1 and #2.

Another computer designed for this purpose is the AN/APA-95. I would like for a moment to go through very briefly the operation of this system in order to show why it is so easy to train a navigator with equipment such as this.

First, latitude and longitude of the point of departure are inserted on the Present Position counters; next, the latitude and longitude of the desired destination are inserted on the destination counters. The aircraft takes off, the autopilot is coupled in, and the aircraft is flown automatically to the destination on a great-

circle course. Meanwhile, ground speed, air speed, and wind speed are continuously available to the operator on the speed dial. Likewise, the direction dial provides true heading, drift angle, magnetic variation, true ground track, transverse track, course to destination, and wind direction at all times.

One feature that both the ASN-7 and the AN/APA-95 computers have is Present Position Storage. This is a feature which allows the Present Position counters to be stopped for reading or setting. During the time that they are stopped for this purpose, aircraft travel is stored. At the end of the period of counter stoppage, the stored travel returns the counters to the proper coordinates with no lost position information. The advantage of such a feature is quite evident.

These computers illustrate that, once the basic input data are available, it is possible to make a navigation system capable of providing almost any information desired. The Doppler input data can also be used with simpler navigation devices such as the AN/ASN-9 or the PHI computers which provide simple rho-theta coursed to the destination.

At this point you may be thinking that this is all well and good—but just how accurate is it? Unfortunately, much as we would like to discuss this subject, it is still classified and must be by-passed. There are, however, a number of comments that can be made now that Doppler equipments have seen many hours of reliable operational service in military aircraft in all parts of the world. As a result of these flights, the applications for Doppler systems are increasing continually. Some of the advantages of Doppler radar—and, consequently, the advantages of Doppler navigation—are as follows:

(1) It is available (in production).

(2) It is accurate (more accurate than any other means of measuring aircraft ground velocity).

(3) It is simple to operate.

(4) It is reliable.

(5) It is easy to manufacture.

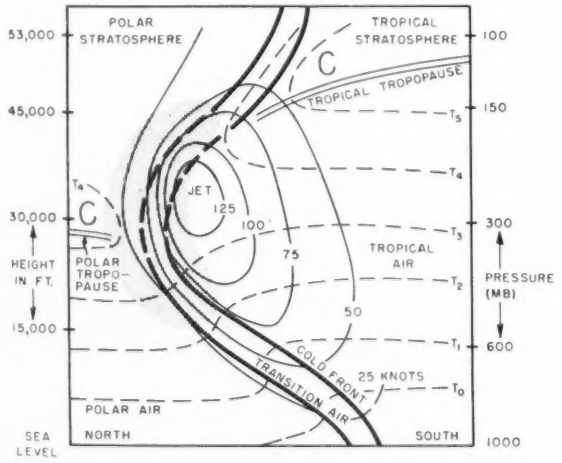


FIG. 8. Jet-stream cross section. (Stippled area indicates most probable zone of air turbulence.)

(6) It is easy to maintain.

(7) In the early models only a 5-min. warmup time was required, and in the new models only a 30-sec. warmup time is necessary.

(8) The altitude range of the equipment is greater than that of available aircraft.

(9) The speed is greater than that of available aircraft.

(10) The equipment can be turned on and started when air borne and is self-aligning in flight.

(11) A minimum of operator training is required.

(12) It provides data never before available regarding the flight vector of an aircraft.

(13) It can be used with a wide array of computers to provide data all the way from simple wind magnitude and direction to data needed for complete automatic navigation and bombing.

(14) It provides a new accurate means of measuring winds continuously and automatically at any altitude.

(15) It provides, for the first time, an accurate means of measuring and calibrating air-speed meters at high altitude.

(16) It provides a new means of eliminating image motion in aerial photographs, giving sharper, clearer pictures.

(17) It opens new approaches in the field of aerial surveying.

(18) It makes possible the use of new techniques in air traffic control.

(19) It makes possible the avoidance of unknown head winds which endanger flight.

(20) It makes possible the best utilization of tail winds, and it reduces jet-stream flying to extreme simplicity.

(21) It provides one of the best means for accurately and automatically guiding an aircraft from a point of departure to a destination.

(22) It makes intercontinental navigation possible with a minimum requirement for Government-supplied ground-based navigation aids.

One interesting program which has made extensive use of the AN/APN-81 Doppler equipment is the Air Force Jet Stream Project, designed to explore the characteristics of very fast air currents high above the earth. As a result of this program, detailed cross sections showing the character of these high-altitude jet streams have been measured. A typical jet-stream section measured with the AN/APN-81 equipment is shown on Fig. 8. This curve and other data were presented in a report by the Air Force to the International Air Transport Association at its eighth annual technical meeting in San Juan, Puerto Rico, in May, 1955. This is illustrative of one of the many applications of Doppler radar.

In conclusion, let us summarize by saying that accurate ground speed and drift angle measuring equipment is now in operational use. It provides military aviation, civil air lines, and aircraft designers with an important new tool which will have a far-reaching effect in all areas of future flight.

John P. Hagen*
Naval Research Laboratory

Radio Tracking, Orbit and Communication for the Earth Satellite†

A chain of receiving stations extending from Washington, D.C., to Santiago, Chile, is being set up to create a radio fence which will intercept a satellite each time it circles the earth. This system was chosen to prove that a satellite is in orbit and to derive geophysical information from perturbations of that orbit.

Introduction

Radio observations of the satellite will be conducted for three main purposes: first, to prove that the satellite is indeed in orbit; second, to determine as rapidly as possible an ephemeris so that acquisition information can be broadcast to other observers; and third, to determine with as great an accuracy as the observations will allow a definitive orbit with its perturbations. It is through the perturbations that the geodetic information will be obtained.

It is planned to launch the satellite in a southeasterly direction from the Air Force Missile Test Center at Cape Canaveral, Fla. The velocity of the launch vehicle at the end of third-stage firing must be great enough so that the centrifugal force in its motion about the center of the earth will just balance gravity. If this condition and the condition that the direction of motion be essentially parallel to the surface of the earth is met, then the object will be on its way in a satellite orbit. The velocity required is about 25,000 ft. per sec. or 18,000 m.p.h.

The planned satellite is a spherical magnesium shell, 20 in. in diameter, containing scientific instruments for the measurement of geophysical quantities, and a minitrack radio transmitter to broadcast tracking signals and telemetering signals containing scientific information.

The planned orbit of the artificial satellite differs markedly from any other orbit studied in the past in celestial mechanics; it is very close to the surface of the primary body, the plane of the orbit has a high inclination, and the primary body (earth) has an equatorial bulge. Because of the first two factors, the earth's shape affects the motion of the satellite.

† A condensation of the paper of the same title presented at the IGY Earth Satellites Session, 25th Annual Meeting, IAS, N.Y., Jan. 28–31, 1957.

* Director, Project Vanguard.

Once the satellite is clear of the launch stand and is on its way high in the atmosphere, it is essentially freed of the rotation of the earth about its axis. The satellite sees the earth as though all its mass were concentrated at a point at the center of the earth with the exception of the nonuniform material in the equatorial bulge. The plane of the orbit stays relatively fixed in space moving with the earth in its motion around the sun. It will be in fact just another moon, but a moon passing a few hundred miles overhead. Because of its proximity, its rate of angular motion about the center will be high, and its apparent rate to an observer on the surface of the earth will be even higher. The angular velocity is such that the period of revolution is about 100 min. And for an observer so located that the satellite will pass through his zenith, the motion will be about 1/5 to 1 deg. per sec. depending on the orbit and its position in the orbit. It will move an angular distance equal to the angular diameter of the moon or sun in 1/2 to $2^1/_2$ sec.

The planned inclination of the orbit is 35°. The latitude of the launch stand is 28°30′, and, since the plane of the orbit must include the center of the earth and the launch point, this represents the minimum inclination to the equator and would be the inclination if the launching were due east. It is advantageous to launch due east to take advantage of the easterly motion of the surface of the earth in its axial rotation. The requirements of the scientific experiments, however, call for an orbit inclined to the equator by some larger amount. An inclination of 35° was decided upon, and this is attained by launching the vehicle some 20° or 30° south of east.

Errors Will Mean Elliptical Orbits

If the terminal velocity vector of the vehicle were of exactly the right magnitude and had a direction exactly perpendicular to a line joining it with the center

of the earth, then the orbit would be circular, and, except for minor deviations, the height of the satellite above the surface would remain the same. There will, however, be unavoidable errors in velocity and direction resulting in elliptical orbits.

If there were no errors, the orbit would be circular and the height above the surface 300 miles. It is hoped to keep the errors so small that the eccentricity of the orbit will not be greater than 0.134 or approximately 1/7.5. For comparison, the eccentricity of the earth's orbit is 0.0167 or 1/60. If the errors are held to this tolerance, then the nearest approach to the earth's surface will be 200 miles and the greatest distance 1,500 miles.

There are two other orbital effects which should be discussed. They are classed as perturbations.

The earth has an ellipsoidal shape due to an equatorial bulge. To the first approximation the gravitational field of the earth could be represented as caused by a point mass at the center and a much smaller mass distributed in a ring at the equator. For distant bodies the attraction caused by the ring as compared with the center would be very small. But for a close satellite the effect can be large. At its maximum the attraction on the close satellite, due to the bulge, approaches 1 per cent of the attraction due to the earth as a whole. The force due to the bulge is, however, not directed along a radius vector and tends to try to tilt the plane of the orbit. This causes the orbit to precess, with the amount of precession for a 35° orbit causing the nodes to regress somewhere between 0.5° and 1° per revolution. In a somewhat similar fashion the effect of the bulge on the motion will cause the point of apogee to change, and in effect the lines of apsides will rotate at about the same rate as the regression of the nodes. Out of the measurement of the rate of precession of the plane of the orbit may well come an improvement in our knowledge of the ratio a/b—the ratio of equatorial to polar radii.

The second perturbation which is of interest here is that of the effect of atmospheric drag upon the orbit. The earth's atmosphere has been probed by rocket techniques to a height of about 150 miles. Average values for the temperature and density to this height are known and are shown in Fig. 1. Extrapolation to heights greater than 150 miles shows that at the height of the planned orbit the pressure will be 10^{-12} A. Our estimates of density at this height could be in error by a factor of three. Even though the pressure is near a perfect vacuum, there will be a measurable drag upon the satellite. Calculations based on a conservative estimate of the density show that the lifetime of a satellite of these dimensions approaching to within 200 miles would be about 15 days. This is felt to be a minimum figure and may be too low by a factor of three. It is through a measurement of the change in the orbit due to drag that a good figure for the density of the atmosphere at these heights will be obtained. In the last several hours of the flight, when drag becomes more and more effective, the orbit will be changing

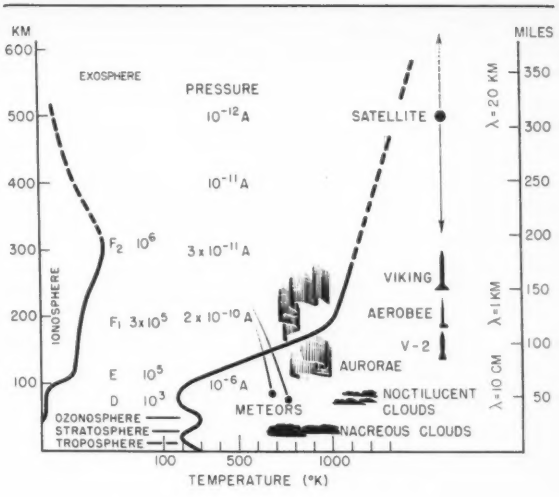


FIG. 1.

rapidly, and, if sufficient closely spaced observations can be made, the variation of density with height for that region can be measured.

In summary, the expected motion of the satellite is one in which there will be an elliptical orbit inclined 35° to the equator with a period of about 100 min. The earth will revolve under the orbit so that on successive passes over the equator the subsatellite point will move to the west about $22^1/_2$ deg. In addition, the plane of the orbit will precess causing the motion of the subsatellite point to be somewhat larger, −23° to 24°. Perigee will move around the orbit so that, if one could be at the equator for each successive passage, the height would increase to a maximum then decrease to a minimum in a regular fashion. Finally the satellite will lose energy to the atmosphere and will gradually fall into a smaller and smaller orbit, gaining speed as it does. Once it goes into this end game, the end will come fast.

On a Mercator projection the orbit would appear as a sine wave moving to the west at a rate of about 16° per hour.

The Minitrack System

It is to catch such an object in its motion and then to measure its position that the radio tracking system is designed. The radio tracking program is under the direction of J. T. Mengel of the Naval Research Laboratory. The Army is cooperating in the Vanguard program by setting up and operating the remote stations. Looking at the Mercator projection we see that, if one built a fence 2,000 miles high extending from 40°N. latitude to 40°S. latitude along any meridian, he would intercept the satellite once each revolution with a minimum number of stations. Just such a fence is being built for the Minitrack operation. Each station is equipped with antennas having narrow fan beam patterns. The pattern will be about 90° by 12° with the long dimension in the north-south plane. If an average height of 300 miles is assumed for the satellite, then a

FIG. 2.

station can intercept a signal from the satellite whenever it is within 300 miles north or south of the station. The total north-south width of the path to be covered by the satellite is 80° of latitude or about 5,500 miles.

The locations of the ten prime Minitrack stations are shown in Fig. 2.

The Minitrack system utilizes a continuous wave transmitter in the satellite, illuminating pairs of ground receiving antennas oriented precisely in a prescribed arrangement. Measurement of the phase difference between the signals arriving at each antenna of a pair provides a measurement of the angular position of the transmitting source relative to the line connecting the two antennas.

A complete Minitrack Ground Station consists of eight antenna arrays, four mounted in the form of a cross oriented north-south and east-west, with 500-ft. legs. These are the "fine" antennas of the system. The other four antennas provide the necessary ambiguity resolution by forming three antenna pairs, two for north-south resolution across the major dimension of the antenna pattern and one for east-west resolution across the minor dimension. This antenna configuration provides four separate antennas for the two fine-measurement antenna pairs and a center point of the system (free of antennas) for mounting calibration cameras.

The phase difference between the satellite signal and a reference signal derived from the frequency difference between the two first local oscillator signals is the same as the original phase difference between the two r-f signals picked up at the two antennas. A phase comparison between these two signals thus provides a measure of the space angle between the radio path to the satellite transmitter and a line connecting the antenna pair. All measurements are controlled by a precision time source, which generates the various reference frequencies required by the system. Timing accuracy will be provided by triggering the digital data readout at prescribed time intervals, accurate to about 1 millisec. under the condition of a single daily check against station WWV. Through the technique of converting to an audio frequency, the bulk of the system amplification occurs in a single high-gain amplifier where the signals from each antenna are amplified identically.

A complete Prime Minitrack Station will include the Minitrack ground antenna configuration, a complete Minitrack electronic unit mounted in its own air-conditioned trailer, a communication setup including 15-kw. transmitters, receivers, and receiving and transmitting rhombic antennas, plus a telemetry antenna system and telemetry ground station units The communication and telemetry ground station units will be mounted in a combined administration-laboratory building which will provide, in addition to office and spare parts storage space, abbreviated cooking and bunking facilities.

Maryland Facility Has Provided a Testing Point

One station of this type has been in operation for some time adjacent to Washington, D.C., at Blossom Point, Md. Known as the Blossom Point Minitrack Test Facility, this station provides a testing point for all of the prototype units produced and an evaluation point for all final units.

The Mark II System

A different type of Minitrack System, called the Mark II System, has been designed to provide a means of observing the satellite orbit at more numerous locations around the earth, thereby determining the precise location of the stations with reference to the complete geodetic system of the earth and providing additional data to be used with the Prime Minitrack data for orbit determination. This system uses a simplified electronic system and as few as two antennas to provide time-of-transit information from the satellite passage. It is designed to operate in conjunction with the Prime Minitrack Network, utilizing the data from this network for ambiguity resolution and thereby eliminating the need for more than four antennas for complete measurement of the satellite passage. Intended for use by universities, professional groups, and advanced amateur radio clubs throughout the world, it should be suitable for obtaining accurate and useful information at many locations where complete Prime Minitrack stations are not feasible. A prototype of a complete Mark II Minitrack station is being built by the Naval Research Laboratory. Drawings and data from this prototype unit will be made available to any prospective user of this type of system in an effort to increase the total number of Minitrack measurements around the world. Its use is invited by participants anywhere in the world between the limits of 40°S. and 40°N. latitude, particularly in Australia, Africa, Southern Asia, and Eastern South America.

The Mark II Minitrack System is based on the use

of phase comparison techniques between the two r-f signals received.

The complete Mark II system for a single antenna pair includes an r-f hybrid junction fed directly by the two antennas, two low-noise 108-mc. amplitude modulation receivers using a common local oscillator, a product detector, an audio amplifier, a recorder unit suitable for recording at least two and preferably four channels of data, plus time, a time standard receiver, and the required antennas. For those locations not close enough to receive the WWV, WWVH, or other standard time signals consistently, an auxiliary precision crystal clock unit is desirable to guarantee the availability of standard time during every tracking event.

The Minitrack Transmitter within the satellite will utilize a crystal-controlled VHF oscillator powered by Mallory mercury cells. An operation frequency of 108 mc. is used to provide as high a frequency as possible consistent with good efficiency and the resultant lower weight within the satellite. A lower frequency would have resulted in excessive ionospheric effect during tracking operations, an effect that already limits ultimate system accuracy. The exact frequency chosen is actually a heretofore unassigned parcel between the commercial FM broadcast band and the aeronautical marker beacon band.

A simple Minitrack transmitter with batteries weighs 13 oz. excluding antenna and external heat shields and will provide about 15 mw. of power for 3 weeks.

Communication From the Satellite

In addition to the Minitrack function of tracking the satellite, the r-f portions of the system from the satellite to the ground are being used as the r-f link for telemetering data from the satellite.

The system sensitivity for the Minitrack System is based on calculated free-space ranges using the following parameters:

P_t = transmitter power, 10 mw.
G_t = transmitting antenna gain, 0.5
G_R = receiving antenna gain, 50
B_B = predetection bandwidth, 10,000 cps
B_p = postdetection bandwidth, 8 cps
f = operating frequency, 108 mc.
N_f = receiver noise factor, 2.5 db.

On the basis of these figures, an operating range of 4,800 miles is obtained for a postdetection signal-to-noise ratio of 30 db., corresponding to 1.8° of phase resolution. This phase resolution corresponds to a space angle resolution of 0.1 millirad., or 20 sec. of arc. This value may be limited by the effect of the ionosphere and troposphere in refracting the radio signal prior to its arrival at the receiving antenna. Such effects may be constant errors, which are a function of zenith angle, or phase noise which is a function of ionospheric or tropospheric turbulence. The presently estimated magnitude of these effects is under 20″ of space angle at small zenith angles during passage late at night, to over 1 millirad. (200 sec.) during daytime passages at large zenith angles.

As soon as observations of time and position of satellite passage are available, calculations of the orbit must be made. These calculations must then be refined with each new acquisition of data. Dr. J. T. Siry is in charge of the theory and analysis work in Project Vanguard and, working with us as a consultant, Dr. Paul Herget of the University of Cincinnati heads up the orbit computation project. The International Business Machine Corporation now has a contract to perform the computations under the direction of Dr. Herget.

Control Center

In this program we do not have a requirement for real-time calculations, but there is a requirement for very high speed calculations so that the orbit parameters and position predictions for chosen locations can be calculated during a single revolution. In order to effect this, all the Prime Minitrack Stations are linked by radio and telegraph with a control center at the Naval Research Laboratory in Washington. Here the observations coming in are filtered and then sent on to the Vanguard Computation Center.

Computation Center

The Computation Center, using a high-speed 704 computer, is being set up in Washington and operated by the International Business Machines Corporation as a prime contractor. A block diagram of the system is shown in Fig. 3. After the orbit has been computed and predictions for the various stations have been made, the information is sent back to the Control Center where messages are sent directly to the Minitrack stations and to the optical stations by way of the Smithsonian Astrophysical Observatory which is in charge of the optical tracking program. In the meantime, as observations from the optical stations come into the Smithsonian and are reduced, this information can be fed into the Vanguard loop to help improve the orbit.

There is a need for two classes of computation for the satellite:

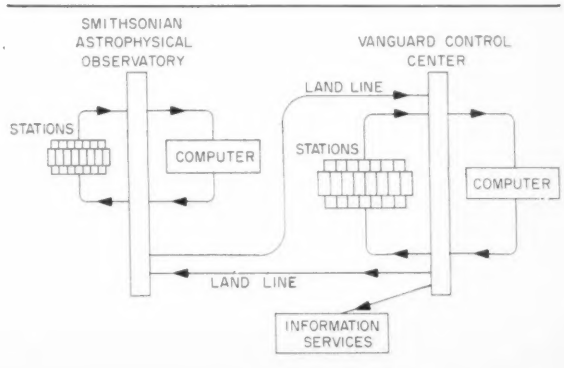


Fig. 3.

(1) Definitive calculations from which can be derived scientific conclusions. These calculations will make use of all the available data and can be made at a leisurely pace.

(2) In-flight calculations which must be good enough to keep track of the satellite and predict future positions to an accuracy of 1° or so. These will be used to alert Minitrack stations, optical tracking stations, and populated areas of the earth over which the satellite will pass during twilight.

In-Flight Calculations

Let us discuss the second class, with which we are more immediately concerned. The following steps must be taken:

(1) The initial determination of the orbit from observations obtained immediately after burnout by the Antigua, West Indies, station. By observing the rate at which the signal passes through the lobe structure, we can obtain a measure of speed, and by correlating the passage through the N-S pattern with the passage through the E-W pattern, we can obtain a velocity vector. However, the errors introduced by measuring through such a short arc and for such a short time may make this prediction of orbit spurious.

(2) The determination of the basic orbit from two or more Minitrack observations. If all goes well, two observations will be made on the first revolution, one at Antigua and the next at San Diego, Calif. These two can determine a circular orbit for the satellite and fix the period and mean height reasonably well. Three observations of good quality are required to determine the elliptic orbit. If the third observation is obtained before more than one or two revolutions, no difficulty will be found in using it; however, if too many revolutions intervene, estimates of the very perturbations we are trying to measure will have to be made in order to combine the measurements.

(3) The calculation of the perturbing effect produced by the equatorial protuberance of the earth. This is a large perturbation causing the line of nodes to regress 1/2 or 1° per revolution of the satellite and hence must be taken into account in combining the observations of the first two stations to obtain the approximate circular orbit. In order to treat observations for a very large number of revolutions, a method evolved for the lunar theory and involving Fourier Series expansions is used. There are four separate series with a total of from 50 to 100 terms in all. The general perturbations will have to be computed by this method as soon as the basic elements of the orbit are known and perhaps at the time of each subsequent improvement of the orbit.

(4) Perturbations caused by atmospheric drag. Many of the factors affecting this calculation are unknown—in fact, the observations will be used to determine the density. It is anticipated that in the course of the calculations improved values will result which will be introduced into later calculations.

(5) Ephemeris calculations and predictions. For the Minitrack stations the prediction need only be that of the time of passage and the identification of the station or stations over which the passage will take place. For the photographic observers the prediction must be somewhat more complicated. For the occasions when the satellite will pass over populated areas during twilight, eclipse-type maps—made with the help of the cathode-ray tube display unit in the Computation Center—will be supplied which will make it possible for the satellite to be located well enough to be in the field of view of binoculars. All the observations will be combined to obtain a definitive orbit.

The Computation Center is now under construction and a team at IBM working with Dr. Herget is preparing the programing of the work for the 704 computers.

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Electronic Equipment Cooling by Simultaneous Heat and Mass Transfer†

Description of a technique for cooling electronic equipment which allows heat to be transferred to an initially high-temperature air stream in such a manner that its exit temperature may actually be lowered below its inlet condition. In this system of cooling, air is assigned the subordinate role of carrier of vapor heat, thus allowing its usage at relatively high temperature levels. Illustrated with examples which use actual experimental data.

Symbols

a = ratio of liquid (water) drop surface area plus wetted tower diffusion chamber surface area to the volume of tower diffusion chamber $\left[\frac{(\text{overall ave. wetted area})}{(\text{tower volume})}\right]$, $\frac{\text{ft.}^2}{\text{ft.}^3}$

A = total heat-transfer surface area (upon which U is based), ft.²

B.t.u. = British thermal unit (3.41 B.t.u. = 1 watt-hour)

C = flow stream capacity rate (FC_p), B.t.u./hour °F.

C_p = specific heat at constant pressure (0.24 for air, 0.45 for water vapor, 1.0 for water), B.t.u./lb. °F.

D_v = diffusivity of vapor, ft.²/hour

f = friction factor, dimensionless

F = fluid flow rate, lbs./hour

G = mass flow rate per unit Ax, (F/Ax), lbs./hour ft.²

h = local convection coefficient of heat transfer, B.t.u./hour ft.² °F.

H = enthalpy of air, B.t.u./lb.

H' = enthalpy of air at saturation, B.t.u./lb.

H.D.U. = height of a diffuser unit—cooling tower characteristic, ft.

H.T.U. = height of a transfer unit—cooling tower characteristic, ft.

j = heat-transfer factor, dimensionless

k = thermal conductivity, B.t.u./hour ft.² °F./ft.

K_x = mass transfer coefficient, lbs. H_2O/hour ft.² (unit humidity potential difference)

M.W. (air) = 28.97

M.W. (H_2O) = 18.02

N.D.U. = number of diffusion units—cooling tower characteristic, dimensionless

N.T.U. = number of transfer units—cooling tower characteristic, dimensionless

p = vapor pressure of water vapor in air at t_{dp}, in. Hg

P = atmospheric or barometric pressure, in. Hg

P_r = Prandtl Number, ($C_p\mu/k$), fluid properties modulus, dimensionless

Q = heat dissipation rate of the electronic equipment, B.t.u./hour

Re = Reynolds Number, (DeG/μ), flow modulus, dimensionless

Sc = Schmidt Number, ($u/\rho D_v$), ratio molecular momentum transfer to molecular diffusivity, dimensionless

S_t = Stanton Number, (h/C_pG), heat-transfer modulus, dimensionless

t = temperature of air, °F.

T = liquid (water) temperature, °F.

U = overall coefficient of heat transfer (based on A), B.t.u./hour ft.² °F.

V = tower diffusion chamber volume, ft.³

x_w = plate or wall thickness, ft.

X = absolute humidity, lbs. water/lb. dry air

Z = overall height of tower, ft.

ϵ = exchanger heat-transfer effectiveness, dimensionless

η = surface area temperature effectiveness, dimensionless

η_0 = total surface area temperature effectiveness, dimensionless

λ = latent heat of vaporization of water (at t_{dp}), B.t.u./lb.

μ = absolute viscosity, lb./hour ft.

ρ = density, lbs./ft.³

ϕ = mathematical proportionality constant

Subscripts

1 = bottom of tower (air inlet, water outlet)

2 = top of tower (air outlet, water inlet)

C = "cold" side of heat exchanger

db = dry bulb (temperature of air)

dp = dew point (temperature of air)

† The authors of this report were assisted by A. Check and R. Moore in the construction of test apparatus and cooling equipment and in recording experimental data. W. W. Tewksbury, Head of the Model Shop, assisted and advised in the fabrication design of the tower cooling system. E. C. Ronyecs assisted in the preparation of the manuscript and illustrations.

The opinions expressed in this report are those of the authors and are not to be construed as representing any policy or official views of the U.S. Navy Department.

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** Project Engineer, Environmental Analysis Branch.

G = gas (air)
h = "hot" side of heat exchanger
H = heat
L = liquid (water)
m = mean
M = mass
max = maximum
min = minimum
v = water vapor
w = water
W = wall
wb = wet bulb (temperature of air)

Introduction

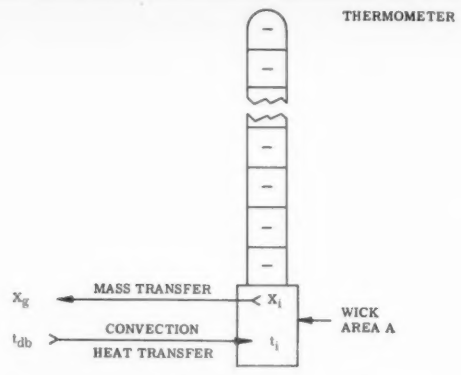
The high Mach Numbers at which present-day military aircraft fly are causing air temperatures in excess of the environmental temperature limits of air-borne electronic components. Also, the low density of air at high altitudes of flight provides only relatively small quantities of air for cooling. The technique of cooling described here is one which allows the usage of high-temperature, low-density air.

Emphasis is placed on the role of heat and mass transfer in relation to the problem of cooling air-borne electronic equipment.

N.T.U. concepts which lend themselves to both one and two component cooling fluid systems and their application are considered in this paper for both cases. The one component method is first described after a brief discussion of the interrelationship of the basic principles of simultaneous heat and mass transfer with related equations.

Basic Principle of Simultaneous Heat and Mass Transfer

The operation of the wet-bulb thermometer (Fig. 1) can be used as a simple method of describing the basic principle of simultaneous heat and mass transfer. Fig. 1 consists of a thermometer surrounded by a wick dipping into water at the same temperature as the surrounding air. The wick is always wet. Assume that unsaturated air at any dry bulb is circulated over the wick. Because the wick is wet and the air is unsaturated, the partial pressure of the water vapor from the wick is greater than that of the water vapor in the circulated air, and water vapor is evaporated from the wick to the air. But the evaporation of water from the wick requires many B.t.u. of latent heat, which must come from somewhere. When the air is initially circulated over the wick, the B.t.u. could come from the wick itself by lowering the temperature of the wick below its initial temperature. But this sets up a temperature differential between the dry-bulb temperature t_{db} and the wet-bulb temperature t_{wb}, and heat starts to flow from the air, by convection, into the wick. Eventually, under this condition, an equilibrium is reached whereby the vaporization is offset by the sensible heat removed from the air. This convenient temperature is called the wet-bulb temperature. The variables shown in Fig. 1 are related by the equation given below. (For details of its derivation see reference 6.)



X = $\frac{\text{LB } H_2O}{\text{LB BONE DRY AIR}}$ IN GAS AND AT INTERFACE

t_{db} = DRY BULB TEMPERATURE OF THE AIR, DEG F

t_i = TEMPERATURE OF AIR AT INTERFACE, DEG F

h = CONVECTION COEFFICIENT OF HEAT TRANSFER, $\frac{\text{B.T.U.}}{\text{HR SQ FT DEG F}}$

K_x = MASS TRANSFER COEFFICIENT, $\frac{\text{LB } H_2O}{\text{HR SQ FT } \frac{\Delta \text{LB } H_2O}{\Delta \text{LB AIR}}}$

Fig. 1. Wet-bulb thermometer.

$$h/K_x = (X' - X)\lambda/(t_{db} - t_{wb}) \qquad (1)$$

From actual experiments performed the value of h/K_x is equal to a constant C (heat capacity of humid air) which for air-water systems is equal to approximately 0.24. Therefore from Eq. (1)

$$h/K_xC_p \cong 1 \qquad (2)$$

Lewis called attention to this relation, and the dimensionless group h/K_xC_p is known as the Lewis Number.[1] It conveys the important information that the convective heat-transfer coefficient is to the mass transfer coefficient as the value of the specific heat of the medium which serves for both heat transfer and mass transfer. Later, under discussion of evaporative cooling apparatus, it will be shown how this effect is advantageously used to cool high-temperature ram air. It thus requires four times as great a potential for a given number of B.t.u. to be transferred by convection as an equal number of B.t.u. by mass transfer.

In the above case, the direction of mass transfer was opposite the convection heat-transfer driving force, but in an actual cooling tower both mass and convection heat transfer could go in the same direction. The point to be remembered is that the direction of the mass transfer driving force is established solely by the difference between the partial pressure of vapor in air at the dew point temperature of the air and the partial pressure corresponding to the water temperature at any points on the same level of the cooling tower. Therefore, air in the unsaturated range can be cooled by injection of water. It may seem strange that air can be cooled in this manner, especially when the temperature of the water is warmer than the air, but the rea-

son is that the water evaporates and takes its heat of evaporation from the air.

Mass and Heat-Transfer Equations

In general, the analogy between heat and mass transfer can be expressed by the Chilton-Colburn j factor relation which is related to the friction factor, f

$$f/2 \cong (h/G\ C_p)\ (P_r)^{2/3} = \phi\ (Re)^{-0.2} = j_h \qquad (3)$$

$$f/2 \cong (K_g P_{bm}/G)\ (S_c)^{2/3} = \phi\ (Re)^{-0.2} = j_M \qquad (4)$$

where $K_g P_{bm}/G$ is the mass transfer modulus, and $S_c = \mu/D_v\rho$ = Schmidt Number expressing the ratio of molecular momentum transfer μ/ρ to molecular diffusivity D_v.

From inspection of Eqs. (3) and (4), it would seem that j_H would be equal to j_M, and therefore it should be possible to calculate the film coefficient of heat transfer h from knowledge of the mass transfer coefficient K_x, or vice versa. It has been shown by various investigators that it is at least a fair approximation to conclude that $j_M = j_H = f/2$ for flat plates, turbulent motion inside tubes, and perhaps single cylinders if form drag is subtracted from total friction to obtain the skin friction. The analogy between heat and mass transfer such as in Eqs. (3) and (4) requires modification to correct for change in boundary-layer conditions before they can be applied for the electronic evaporative-type cooling system described herein.

Electronic Cooling Tower System

The electronic cooling system shown in Fig. 2 is a countercurrent cooling tower. A characteristic of this type of cooling system is to reduce the dry-bulb temperature of high-temperature air as it enters the diffusion chamber of the electronic equipment. This is achieved by a fine spraying of many very small liquid

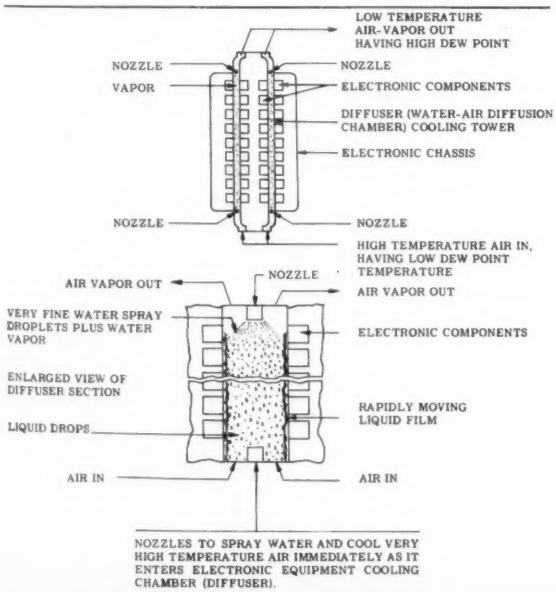

LOW TEMPERATURE AIR-VAPOR OUT HAVING HIGH DEW POINT
NOZZLE
VAPOR
NOZZLE
ELECTRONIC COMPONENTS
DIFFUSER (WATER-AIR DIFFUSION CHAMBER) COOLING TOWER
ELECTRONIC CHASSIS
NOZZLE
NOZZLE
HIGH TEMPERATURE AIR IN, HAVING LOW DEW POINT TEMPERATURE
AIR VAPOR OUT
NOZZLE
AIR VAPOR OUT
VERY FINE WATER SPRAY DROPLETS PLUS WATER VAPOR
ELECTRONIC COMPONENTS
ENLARGED VIEW OF DIFFUSER SECTION
RAPIDLY MOVING LIQUID FILM
LIQUID DROPS
AIR IN
AIR IN
NOZZLES TO SPRAY WATER AND COOL VERY HIGH TEMPERATURE AIR IMMEDIATELY AS IT ENTERS ELECTRONIC EQUIPMENT COOLING CHAMBER (DIFFUSER).

Fig. 2. Electronic cooling tower chassis.

(water) drops into the incoming air stream; this not only reduces its dry-bulb temperature but has the effect of increasing the heat capacity properties of air as it enters the electronic equipment. A better picture of this condition can be had by recalling that the release of heat by the electronic equipment manifests itself by an increase in enthalpy, (B.t.u./lb. air), of the air stream.

For air alone, the heat capacity at constant pressure is relatively low—namely, 0.24(B.t.u./lb. °F.)—and, from the relationship

$$\Delta H = (C_{pm})\ (t_{db2} - t_{db1}) \qquad (5)$$

it can be seen that the temperature rises rapidly when air is used as the coolant. This cooling process increases the heat capacity of the entering air. This effect can be better understood by the relationship for enthalpy of unsaturated air expressed as

$$H = XC_{pw}t_{dp} + X\lambda_{tdp} + 0.45X\ (t_{db} - t_{dp}) + 0.24\ t_{db} \qquad (6)$$

From the above expression, it can be seen that there are other heat capacities for removing heat from the electronic equipment, the most important of which is the latent heat of vaporization of water (λ) that can expend about 1,050 B.t.u./lb. without a temperature rise, as well as the specific heat of water and vapor (C_{pw},C_{pv}).

Another primary design feature of the system pertains to the technique of making simultaneous mass transfer of heat the predominant means of cooling over conventional air convection heat transfer, thus providing a means of relegating air to the minor role of "carrier of vapor" heat rather than the major role of "coolant."

As indicated above, the small liquid drops sprayed into the incoming air stream reduces the dry-bulb temperature and accordingly increases the dew-point temperature of the incoming air. However, the incoming air is still not near saturation, thus leaving a condition for a mass transfer driving force to exist from the rapidly moving thin liquid environment shown flowing over the inside surface of the diffusion chamber to the unsaturated air. Experimental data have verified that the rapidly moving film acts as a protective low-temperature barrier by the evaporation of water at temperatures much below the boiling point. The equipment "feels" only the low-temperature liquid film.

It is observed that this cooling system aids the formation of a turbulent core even at low flow rates by the artificial stimulus of the water spray drops flowing countercurrent to the hot air stream.

Finally, the system shown in Fig. 2 alleviates stagnant gas heat insulating (air) films around the surfaces of the electronic chassis by introducing the diffusion of water vapor heat through the stagnant film.

General Discussion of N.T.U. Concept for Conventional Heat Exchangers

In preceding sections of this paper, it was pointed out that the concept of N.T.U. and related concepts

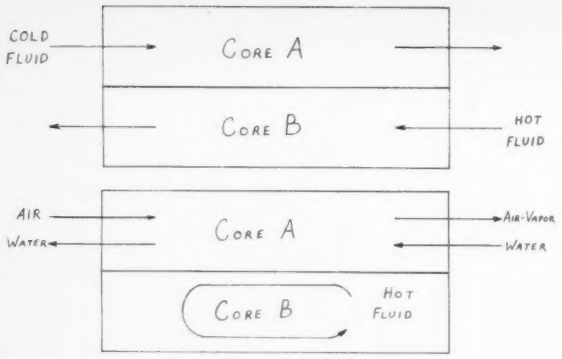


DIAGRAM 1 (*Top*), DIAGRAM 2 (*Bottom*).

of H.T.U., N.D.U., and H.D.U. appear to lend themselves to both one and two fluid components. The concept of N.T.U. for one fluid component cooling is now briefly presented. (For derivations and more detailed discussions, see reference 6.)

It is important to recognize the concepts of N.T.U. for conventional heat exchanger utilizing one fluid component and those to be discussed later under the simultaneous heat and mass transfer system using two components.

In Diagram 1, depicting the conventional one fluid component type of countercurrent heat exchanger, the fluids passing through cores A and B can be liquid or gas. It is understood that in either core there is only one fluid.

In Diagram 2, depicting the countercurrent simultaneous heat and mass transfer system to be described later, core B corresponds to the inside of the pressurized electronic equipment having only one circulating fluid (air). However, in core A there are two fluids in intimate contact (air and water), one fluid (water) which is diffusing into the gas (air) stream.

It has already been mentioned that in the conventional type of direct heat exchanger, the performance of either core is defined in terms of j factor data versus Reynolds Number. Let us assume for the time being that the data for a specific core as used on the electronic equipment are available. With these data it is possible to determine the local film coefficient of heat transfer h for both cores covering the hot and cold fluid (air to air) or (gas to gas), respectively. The interrelationship of the two local film coefficients, and the resistance of the wall separating the two cores to overall coefficient for the conventional two-fluid heat exchanger, is related to heat-transfer performance as follows:

$$\frac{1}{U_c} = \frac{1}{\eta_{0c} h_c} + \frac{x_w}{(A_W/A_c)k} + \frac{1}{(A_h/A_c)\eta_{0h} h_h} \qquad (7)$$

where U_c is based on a unit of cold side total area including fin or extended area. A_W denotes the average wall or prime area; η_{0h} and η_{0c} denotes the temperature effectiveness of the total areas A_h and A_c, respectively.

The heat exchanger effectiveness can be defined as indicated below:

$$\text{Heat exchanger effectiveness} = \frac{C_h(t_{h\,in} - t_{h\,out})}{C_{min}(t_{h\,in} - t_{c\,in})} = \frac{C_c(t_{c\,out} - t_{c\,in})}{C_{min}(t_{h\,in} - t_{c\,in})} \qquad (8)$$

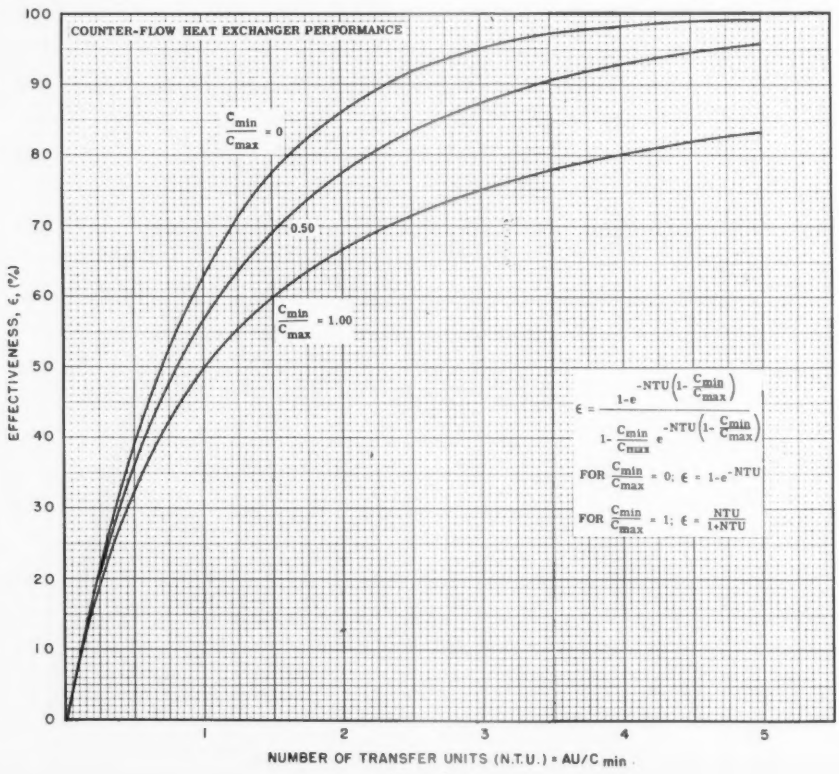


FIG. 3

where C_{min} is the smaller of the C_h and C_c magnitudes.

The number of transfer units is then defined as follows:

$$\text{N.T.U.} = \frac{A U_{av}}{C_{min}} = \frac{1}{C_{min}} \int_0^A U dA \qquad (9)$$

where A is the same transfer area as used in the definition of U. Generally in design work U can be treated as constant. Thus it is possible to express the exchanger heat-transfer effectiveness

$$\epsilon = \phi \text{ (N.T.U., } C_{min}/C_{max}\text{, flow arrangement)} \qquad (10)$$

similar to that shown by Fig. 3.

It can be shown that the heat exchanger effectiveness for countercurrent heat exchanger can be expressed as follows:

$$\epsilon = \frac{1 - e^{-\text{N.T.U. } (1 - C_{min}/C_{max})}}{1 - C_{min}/C_{max}\, e^{-\text{N.T.U. } (1 - C_{min}/C_{max})}} \qquad (11)$$

Concept of N.T.U. and H.T.U. for Two Component Simultaneous Heat and Mass Transfer Electronic Cooling System

In the simultaneous heat and mass transfer system not only are there two components (air and water) but in the diffuser (cooling chamber) these two components are in intimate contact and the liquid component (water) is actually going through a change of phase—from liquid to vapor. The concepts of N.T.U. under these conditions require a different treatment.

Fig. 4 illustrates a block diagram of the conventional adiabatic cooling tower. The gas loading G remains constant throughout the tower because it is based upon the bone dry gas only. The liquid loading is not quite constant, however, owing to the evaporation of water into the bone dry air. The saturation loss from water to air amounts to less than 2 per cent of the water circulated over the tower and may be considered constant without introducing a serious error. Hence

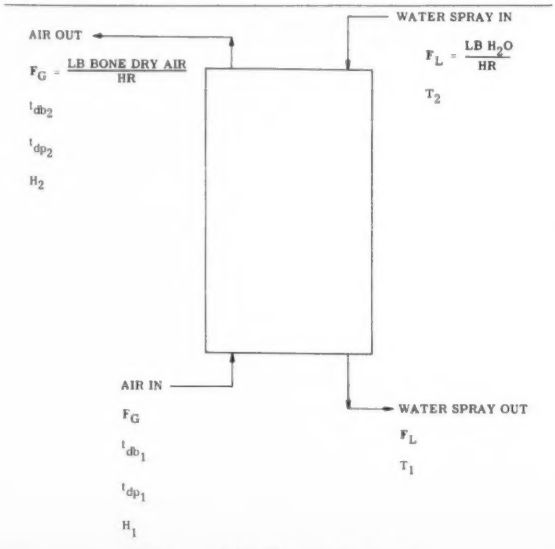


Fig. 4. Adiabatic cooling tower

$$F_L C_{pw} dT = F_G dH = K_x a\,(H' - H)\, dV \qquad (12)$$

This equation is the key equation for calculation of the design and the analysis of performance in cooling towers. K_x is the overall mass transfer rate term analogous to U_c in heat exchangers. However, in heat exchangers the heat-transfer surface is usually known or can be readily computed. In the cooling tower, the value of a = [(area of drops + tower S.A.)/(volume of tower)] cannot be determined directly since it is composed of a random disposition of droplet and film surface both on droplet and metallic surface of diffuser. The inability to calculate a is overcome by experimentally determining the product $K_x a$ as a *whole* for a particular type of tower and at specific rates of flow for the diffusing liquid comprising the system.

Eq. (12) can be rearranged as shown below to define N.T.U. and N.D.U.:

$$\int \frac{dH}{H' - H} = K_x a \frac{V}{F_G} \qquad \text{Number of Transfer Units} \qquad (13)$$

$$\int \frac{dT}{H' - H} = K_x a \frac{V}{F_L} \qquad \text{Number of Diffusion Units} \qquad (14)$$

The integrals shown above over the entire height of the tower give the number of times the average potential may be divided into the total desired enthalpy change of the gas or the liquid. It indicates the size of the task that must be accomplished.

Different heights of various diffusion towers are required for the accomplishment of a transfer unit depending on how it is physically constructed. From experiments on a particular type of tower of overall height Z, it is possible to determine experimentally the number of transfer units accomplished by it, and the height of a single transfer unit H.T.U. will then be

$$\text{H.T.U.} = Z/\text{N.T.U.} \qquad (15)$$

or for diffusion basis

$$\text{H.D.U.} = Z/\text{N.D.U.} \qquad (16)$$

Enthalpy Balance

A complete enthalpy balance for the cooling process may be calculated for the evaporative spray tower electronic cooling system by use of the following equation:

$$Q = F_G\,[X_2(0.55\, t_{dp_2} + \lambda_2 + 0.45\, t_{db_2}) - X_1(0.55\, t_{dp_1} + \lambda_1 + 0.45\, t_{db_1}) + 0.24(t_{db_2} - t_{db_1})] + F_L\, C_{pw}\,[T_1 - T_2] \qquad (17)$$

We can, however, calculate a heat balance for the system by using the measured values of P, F_G, F_L, t_{db_1}, t_{dp_1}, T_1, T_2, and Q, which are easily determined values and may be measured with a reliable degree of accuracy, thus eliminating the reliance upon the measurement of exit conditions (especially if there is liquid entrainment) to get a good heat balance.

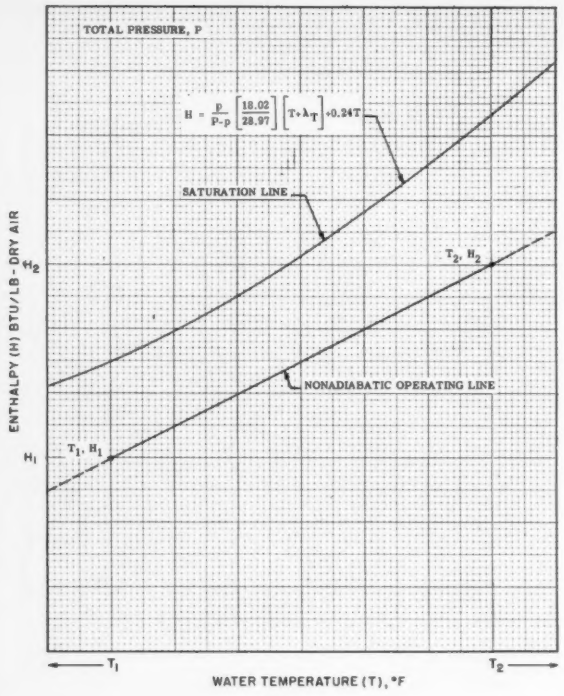


FIG. 5.

Calculation of Enthalpy-In Condition of the Air (H_1) at Any Pressure Condition of Operation

H_1 is calculated from the measured values of t_{db_1} and t_{dp_1} by using

$$H_1 = X_1 \left[0.55\, t_{dp_1} + \lambda_1 + 0.45\, t_{db_1}\right] + 0.24\, t_{db_1} \quad (18)$$

Next, proceed to calculate the enthalpy condition of the exit-air (H_2) using the measured parameters and H_1 calculated above.

Calculation of the Enthalpy-Out Condition of the Air

Before proceeding further, draw or construct an enthalpy H vs. water temperature T diagram depicting the saturation line and operating line at pressure P at which we are operating the cooling spray tower. The temperature enthalpy diagram indicates the potential for energy transfer at any section of the tower (in this case the potentials are determined at the inlet and exit conditions). The potential is the difference in the ordinates of the saturation and nonadiabatic operating lines for the water temperature at the plane in the tower which is under consideration (again the inlet and exit conditions in this case).

Construction of the Temperature-Enthalpy Diagram

See Fig. 5.

(1) *Plotting the Saturation Line*—Select a suitable piece of rectangular coordinate graph paper (IXI). The abscissa is the water temperature T within the range of T_1 and T_2 (extend in each direction by a few degrees in order to get a better overall view of the operating lines). The ordinate is the enthalpy of air determined at the corresponding T values (make sure that the calculated value of H_1 is included in the range of H plotted as the ordinate). In order to get the saturation line at P, plot T vs. the H corresponding to T. H is determined by using the expression

$$H = [p/(P - p)]\,[18.02/28.97]\,[T + \lambda_T] + 0.24T \quad (19)$$

since at saturation $t_{db} = t_{dp} = t_{wb}$.

Select the values of T in the range shown on the diagram, calculate the corresponding H from Eq. (19) above, and plot the saturation line on the T vs. H diagram using T as the abscissa and corresponding calculated H as the ordinate.

(2) *Plotting the Nonadiabatic Operating Line*—Since we are dealing with a system which is constantly adding, heat being dissipated by the electronic equipment, we have consequently a nonadiabatic process taking place so that we plot a nonadiabatic operating line in order to obtain the energy transfer at the inlet and exit of the tower. (This is in contrast to the adiabatic process existing in the commercial spray towers which are in everyday use where no external heat is added to the system.)

Point T_1H_1 of the operating line is plotted from the measured value of T_1 and the calculated value of H_1. Point T_2H_2 of the operating line is determined by the

TABLE 1
Summary of Representative Experimental Data*

Test No.	F_G† lbs./hour	F_L† lbs./hour	t_{db_1} °F.	t_{dp_1} °F.	(Out) T_1 °F.	(In) T_2 °F.	P in. Hg	Measured t_{db_2} °F.	Ave. Case Temp. °F.
91	100	62.3	139.4	39.2	90.2	101.6	29.69	99.4	111.8
92	100	62.3	159.7	42.8	92.8	102.9	29.48	105.6	114.9
93	100	62.3	182.9	42.8	94.4	100.6	29.68	103.2	114.9
94	100	62.3	206.8	57.7	98.9	101.5	29.68	110.2	120.6
95	100	62.3	235.4	48.2	103.2	102.6	29.52	111.0	119.4
96	100	62.3	254.3	50.0	106.8	103.0	29.76	113.0	124.8
107	150	194.9	105.2	43.7	91.4	102.4	29.79	97.1	112.7
116	150	38.4	109.6	25.7	82.2	111.4	29.54	102.4	107.4
125	70	99.2	107.4	17.6	97.6	106.2	30.01	103.7	124.1
129	70	194.9	114.8	37.4	102.5	114.2	29.58	109.3	118.8

* 500-watt load; 350 watts outer chamber; and 150 watts inner chamber.

† F_G is the airflow rate in lbs./hour and is the quantity of air actually circulated and expended in the cooling process. F_L is the liquid rate in lbs./hour and is the quantity of liquid circulated through the cooling tower; it does not represent the quantity of liquid expended (evaporated). Actually the quantity of liquid expended is a small part of the liquid flow rate F_L and is determined by a material balance. Liquid evaporated = $F_G(\Delta X)$.

measured value of T_2 and the value of H_2 which is determined from

$$H_2 = H_1 + dH \tag{20}$$

where

$$\left.\begin{aligned} dH &= (Q + F_L C_{pw} dT)/F_G \\ dT &= (T_2 - T_1) \end{aligned}\right\} \tag{21}$$

The Q value used above in the heat balance relationships is the net Q value, this being the net heat dissipated by the equipment after accounting for all heat losses.

(3) *Enthalpy Balance*—Knowing H_1 and H_2, we can proceed to check the enthalpy balance by using

$$Q = F_G\,[H_2 - H_1] + F_L\,[T_1 - T_2] \tag{22}$$

[which is the same form as Eq. (17)].

Example Problem for Evaporative Spray Cooling Tower

The following example will illustrate the calculation procedure for determining the characteristics of the evaporative spray cooling tower principle for cooling air-borne electronic equipment investigated at the U.S. Naval Air Development Center. Actual experimental data are used in the following example (test #107). (See Tables 1 and 2.)

Calculation of the Enthalpy-In Condition of the Air at Atmospheric Pressure

Using Eq. (18)

$$H_1 = 0.006024\,[0.55 \times 43.7 + 1{,}068.54 + 0.45 \times 105.2] + 0.24 \times 105.2$$
$$= 32.12 \text{ B.t.u./lb.}$$

Calculation of the Enthalpy-Out Condition of the Air

Construction of the temperature T - enthalpy H diagram

(1) *Plotting the Saturation Line*—for example, to get H corresponding to $T = 88°$F., use Eq. (19)

$$H = (1.3351/28.4549)\,[18.02/28.97]\,[88 + 1{,}043.54] + 21.12$$
$$= 54.14 \text{ B.t.u./lb.}$$

p at $T = 1.3351$ in Hg, λ at $T = 1{,}043.54$ B.t.u./lb.

The same procedure is followed for the range of temperatures on the abscissa up $T = 104°$F. The saturation line is obtained by connecting all points from $T = 88°$F. to $T = 104°$F. (in order to obtain a smooth curve at least 10 points should be plotted). See Fig. 6.

TABLE 2

Measured Data		Calculated Data
Q	= 1,705 B.t.u./hour	λ, based on the dew-point temperature (t_{dp_1}) = 1,068.54 B.t.u./lb.
Net Q	= 1,284 B.t.u./hour (after heat losses are accounted for)	$X_1 = [p_1/(P - p_1)]\,[18.02 \div 28.97]$ where p_1 is the vapor pressure of H_2O in air at $t_{dp_1} = 0.28573$ in Hg
F_G	= 150 lbs./hour	
F_L	= 194.9 lbs./hour	
t_{db_1}	= 105.2°F.	
t_{dp_1}	= 43.7°F.	
T_1	= 91.4°F.	X_1 = 0.006024 lbs. H_2O/lb. dry air
T_2	= 102.4°F.	
P	= 29.79 in Hg	

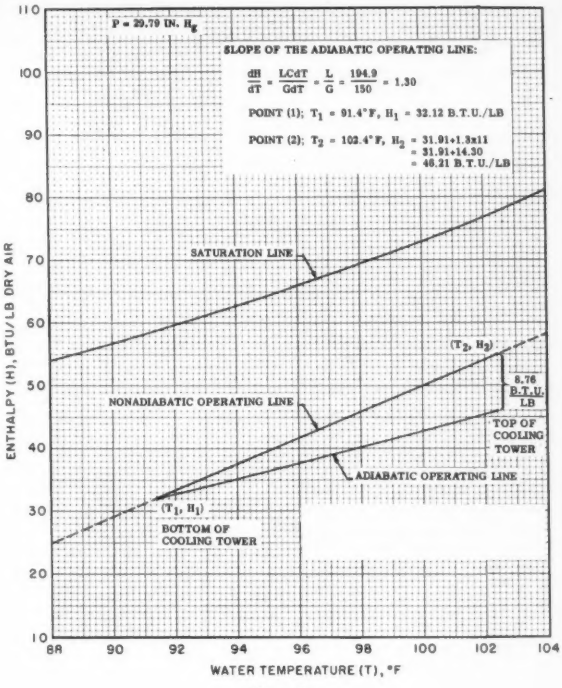


FIG. 6.

(2) *Plotting the Nonadiabatic Operating Line*—Point T_1, H_1 is obtained from the calculated value of H and the measured value of T_1.

Point T_2, H_2 is obtained by calculating H_2 from Eqs. (20) and (21) and the measured value of T_2.

$$H_2 = 54.97 \text{ B.t.u./lb.}$$

The solid line between points T_1, H_1 and T_2, H_2 represents the nonadiabatic operating line

$H_2 = 54.97$ B.t.u./lb. is the enthalpy-out condition of the air.

Enthalpy Balance Calculation

Using Eq. (23)

$$Q = 150\,[54.97 - 32.12] + 194.9\,[91.4 - 102.4]$$
$$= 1{,}284 \text{ B.t.u./lb.}$$

This agrees with the heat (net Q) being dissipated by the equipment.

Calculation of Number of Transfer Units (N.T.U.)

Graphical integration: Using Eq. (13),

$$\text{N.T.U.} = \int \frac{dH}{H' - H} = \frac{H_2 - H_1}{(H' - H)_{ave}} = 0.946$$

(from Fig. 6)

Calculation of Number of Diffusion Units (N.D.U.)

Graphical integration: Using Eq. (14),

$$\text{N.D.U.} = \int_{T_1}^{T_2} \frac{dT}{H' - H} = \frac{T_2 - T_1}{(H' - H)_{ave}} = 0.455$$

(from Fig. 6)

Calculation of Height of a Transfer Unit (H.T.U.)

Using Eq. (15), H.T.U. = 1.59 ft., and Z = 1.5 ft. (actual tower height).

Calculation of Height of a Diffuser Unit (H.D.U.)

Using Eq. (16), H.D.U. = 3.30 ft.

Suppose we desire the liquid temperature to enter at T_2' = 98°F. In order to calculate the new liquid flow rate F_{L_2}' on the same operating line refer to Fig. 6.

Using Eq. (21) and rearranging and changing to new conditions,

$$F_{L_2}' = [F_G (H_2 - H_1) - Q]/[C_p (T_2' - T_1)]$$

where H_2' = 45.8 B.t.u./lb. (from Fig. 6); T_2' = 98°F.; and Q, F_G, H_1, and T_1 are given above.

$$F_{L_2}' = [150\ (45.8 - 32.12) - 1{,}284]/(98 - 91.4)$$
$$= 116.4 \text{ lbs./hour}$$

This changes all values of N.T.U. and N.D.U.

Conclusions

(1) The high speeds and high altitudes at which advanced designs of aircraft fly would seem to preclude the use of high-temperature and low-density air. The simultaneous heat and mass transfer cooling system is considered to be a means of allowing its usage. Some of the important design characteristics and advantages allowing its usage are as follows:

(a) The system uses air mainly as a carrier of vapor heat and as such will permit the use of air despite the fact that its dry-bulb temperature is above the allowable limits of the electronic components.

(b) The system utilizes extremely small quantities of air and liquid to do the cooling job.

(c) The relatively small quantity of air required together with the consequent saving in fuel consumed in overcoming momentum drag of the aircraft more than compensates for the addition of the liquid coolant.

(d) The ability of this system to evaporate the liquid (water) at temperature much below the boiling point.

(e) The "cool" liquid film environment rapidly moving over the surface of the electronic equipment acts as a protective barrier to any close high-temperature environment surrounding the electronic equipment.

(f) The permissible operation of this system with high-temperature air-in which is reduced to a satisfactory operating level.

(g) The small mass transfer driving force necessary to compensate for the convection driving force which is in the opposite direction for high-temperature air-in.

It is the opinion of the authors that the application of direct contact heat-transfer techniques which permit the air-borne cooling system to take advantage of simultaneous heat and mass transfer principles has not received the degree of acceptance it appears to merit for cooling of air-borne electronic equipment.

(2) The simultaneous heat and mass transfer system of cooling has been shown to be the practical application of a thermodynamic principle—namely, that the transfer of heat (energy in transition) can be accomplished with reductions in dry-bulb temperatures.

(3) Review of typical experimental data (see Table 1) shows that little was achieved in reducing electronic average case temperatures to relatively lower temperature levels by using the higher gas and liquid flow rates. The writers interpret this to indicate that perhaps lower liquid and gas rates could have been used to maintain satisfactory temperature level (equipment permitting) and is an indication that a cooling system of this type can operate effectively at flow rates lower than those used with possibly a smaller diffusion chamber.

Additional Design Studies Being Performed at the U.S. NADC on the Simultaneous Heat and Mass Transfer Cooling System

Supplementing the above presentation will be a future paper on the activities now in process at the U.S. Naval Air Development Center. The subject of this paper will be the correlation of the experimental data into a simultaneous heat and mass transfer cooling system design technique to the type of system described above. The development of realistic efficiency and heat-transfer coefficient and thermal conductance factors and calculations will be based upon the measured parameters and case and component critical hot spot temperatures. It will also take into consideration all of the various parameters involved and their effects on aircraft penalties such as fuel consumed in overcoming momentum drag, etc. Correlations of N.T.U., N.D.U., etc., with F_G, F_L, t_{db}, t_{dp} hot spot temperatures will also be included together with the concepts of gas and liquid resistances, directions of mass and convective driving forces along the tower length for a cooling system of this type, and t_{db} variation through the cooling tower length.

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ELECTRONICS IN AVIATION

". . . it is now feasible to develop a central digital computer system for transport aircraft which can measure up to the exacting requirements of scheduled aeronautical operations."

Air-Borne Computers Will Reduce Cockpit Workload

Vernon I. Weihe*
Air Transport Association of America, and Melpar, Inc.

Introduction

Shortly after World War II a number of large-scale special- and general-purpose electronic digital computers were produced for fixed installations. These "giant brains" were large in size and contained thousands of radio tubes and circuits. Since that time digital computers of many types have been designed and placed in service, and within the last few years a number of relatively small and lightweight air-borne digital computers have also been developed.

Recent developments in semisolid conductors, ferrites, transducers, and sensors are making possible large computing capacity and high computation speed with small weight and size. New transistors, better printed circuits, higher speed magnetic storage elements, new ferromagnetic computing components, and other improved devices and techniques are now available. These, along with advanced system concepts, now make it feasible to construct an air-borne digital computer having good reliability and low electrical power consumption.

In addition, there are better sensors and transducers for aeronautical uses; there are also available many types of analog-to-digital and digital-to-analog converters. These can facilitate smoother integration of computer equipments into the electrical and mechanical systems of existing aircraft.

The astonishing story of progress in the computer field is beyond the scope of this paper; however, it is, I believe, without parallel in the history of technological development. The rate of introduction of new components is now so great that some manufacturers are reluctant to work with available components lest their systems become obsolete before the designs are finished.

Meanwhile, the need for more and better air-borne automatic computation increases with each new aircraft design. Most of the computers used in aircraft today are of either the mechanical or the electromechanical analog types, designed, unfortunately, for specific purposes and not adaptable to the accomplishment of a multiplicity of varied computing functions. However, they have established an admirable record for reliability which, until recently, has gone unchallenged by digital computer designers.

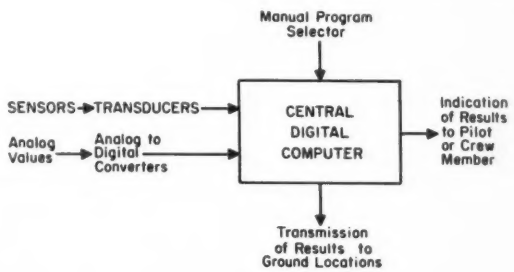

Fig. 1.

Using today's advanced techniques, it is now feasible to develop a central digital computer system for transport aircraft which can measure up to the exacting requirements of scheduled aeronautical operations. Not only can the equipment be made compact enough for dual installation, but also the use of certain self-healing features can be considered as a means for further raising the overall level of system reliability.

A number of air lines have already realized operational improvement through the application of ground-based computer systems to flight planning and reservations control. The Common System of Air Navigation and Traffic Control is expected to employ computer techniques for air traffic control and for air weather dissemination.

Computer systems in use or in development for new transport aircraft include the Air Data System, VORTAC Course Line Computer, VORTAC Pictorial Display, Aircraft Detection and Collision Avoidance, Doppler Dead Reckoning Navigation Computer, and Manual E-6B or equivalent.

A generalized computer block diagram is contained in Fig. 1.

Presented at the Electronics Session, 25th Annual Meeting, IAS, N.Y., Jan. 28–31, 1957.

* Staff Consultant, Air Navigation and Traffic Control.

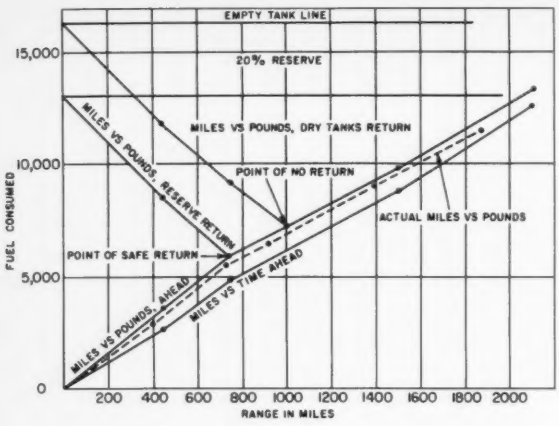

FIG. 2.

LONG-RANGE OPERATIONS

Each year the emphasis on preflight planning and cruise control increases. New transport aircraft, soon to become operational, will require even greater attention to these factors in order to retain a suitably high level of operational safety and efficiency. In this area, computers could effect great improvement.

Long-range cruise control charts (or "how-go-zit" charts), Figs. 2–4, are now used in many forms to assure the proper accountability between such factors as temperature, pressure altitude, fuel consumption, distance range, and elapsed time. These charts cover *point of no return* and *point of safe return* with fuel reserves for both normal and emergency cruise conditions. Emergency conditions, such as one or two engines out or the necessity to cruise at an unfavorable altitude, also can be taken into account.

At the present time, much of the information is contained in operations manuals, and a crew member manually transcribes data throughout the flight.

These tasks are uniquely applicable to automatic handling by a central computer in a way which can provide the pilot and the crew with more information in a more accurate form. The central computer should be able to handle this type of workload on demand or on an infrequent schedule basis without any material effect upon those applications which require greater speed and more continuous operation. Corrected temperature and altitude will be permanently programed into the central computer from appropriate sensors and transducers, while time and range (traversed and to go) are both expected to be available as normal outputs from the Doppler dead reckoning portion of the overall system.

By totalizing fuel flow, the computer, on demand, can indicate to the pilot the fuel reserves expected at destination and at the alternate terminal, as well as the endurance capability of the aircraft in hours and minutes. It can indicate *point of no return* and *point of safe return* for various cruise altitudes under both routine and emergency operating conditions. The crew can then review the overall status without laborious manual computations and can make quick decisions, thereby providing significant advantages to both the safety and the economy of operations.

The system can also provide a routine indication of gross weight so that the pilot can accurately judge the aircraft's performance during approach and landing. Gross weight can be interpreted by the computer into indications of desired approach speed, minimum safe speed, and stall speed. Both normal and decelerated stop distances on the runway can also be indicated. The pilot can determine what the landing weight will be and establish whether or not the runway selected, the wind component, and the landing roll are within his operating criteria.

EN ROUTE PERFORMANCE OPERATING LIMITATIONS

It is normal for aircraft operators and regulatory bureaus to be concerned with operating limitations imposed by ambient temperature, airport altitude, length of runway, etc. Specific operating criteria are defined for each type of aircraft for both normal and emergency conditions.

The height of ground in the vicinity of the airport along the intended track is related to the rate of climb

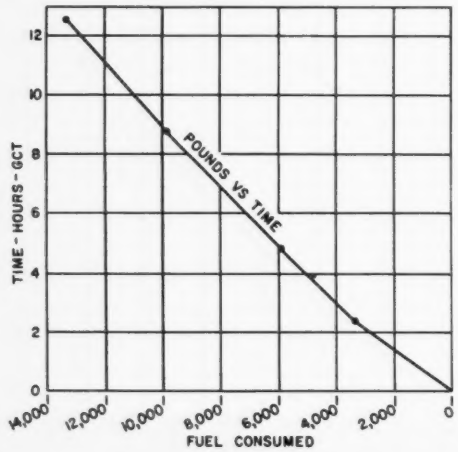

FIG. 3.

122,000 TO 118,000 LBS.								
	BHP	RPM	INBD BMEP	#/HR /ENG	GPH	IAS KNT	TAS KNT	TIME HRS
High Blower	1780	2400	175	791	528	191	267	1.26
	1675	2350	168	744	496	184	253	1.34
	1670	2350	168	745	497	186	252	1.34
	1625	2300	167	723	482	184	245	1.38
	1620	2300	166	723	482	186	243	1.38
Low Blower	1650	2400	162	708	472	190	244	1.41
	1710	2400	168	731	488	198	249	1.37
	1690	2350	170	720	480	198	245	1.39
	1670	2300	171	711	474	198	242	1.41
	1645	2250	173	701	468	199	239	1.43
	1570	2200	168	673	449	194	230	1.49
	1520	2150	167	654	436	192	224	1.53
	1520	2150	167	656	438	194	222	1.52

Four Engine Long Range Cruise Chart - 1049G

FIG. 4.

under various power-plant malfunctions and other emergency conditions. Drift-down procedures and fuel jettisoning indoctrination are covered in an overall plan which maintains a high level of safety without unduly decreasing the practical utility of the aircraft.

The air-borne central computer can be applied to a number of important monitoring functions in connection with this phase of aeronautical operations. For instance, the following limitation might be imposed on take-off operations with one engine inoperative.

"Take-off weight must be such that the rate of climb will exceed

$$0.06 - (0.08/N)V_{s_0}^2$$

(where N is the number of engines installed and V_{s_0} is in miles per hour) at an altitude of at least 1,000 ft. above the elevation of the highest ground or obstruction within 10 miles on either side of the intended track."[2]

Since computer sensors must provide (for other purposes) air temperature, pressure altitude, weight, etc., it should be a straightforward matter to insert the obstruction height information and learn from a computed solution in accordance with the above formula what the allowable gross weight is. Alternatively, one might insert the information to determine how much fuel can be accepted without exceeding the computed allowable gross weight.

With a given fuel limitation, one can request and obtain information concerning the type of cruise control which should be used for the conduct of the flight with the proper fuel reserves.

Prior to starting a flight, the computer might be employed to provide an indication of the effects of runway gradient, cross-wind component, turn radius, etc. The following formulas are typical of this type of calculation.

Effect of Runway Gradient—The effect of gradient on accelerate distance or decelerate (stopping) distance and the ground run portion of the take-off path can be calculated using a formula such as

$$S_G = S/\{1 \pm [(2Sg \sin \lambda)/V_2]\}$$

where

S = acceleration distance without gradient
g = 32.2 ft./sec.^{2}
V = V for accelerate distance
= V_2 for take-off path
λ = angle of gradient

Effects of Wind—10 m.p.h. or less:

$$S_w = S[(V_2 - V_w)^{1.85}/V_2]$$

greater than 10 m.p.h.:

$$S_w = S[(V_2 - V_w)^2/V_2]$$

where

S_w = runway required with wind
S = runway required with *no* wind
V_2 = take-off speed
V_w = 0.5 × head-wind component
= 1.5 × tail-wind component

En Route Navigation

There are two navigational systems which require computed outputs in order to achieve full in-service utility:

(1) VORTAC—The rho/theta navigational concept, involving the combination of bearing and distance determination from a point source location, needs either a course-line computer, a pictorial display, or both in order to facilitate arbitrary course flying, automatic flight, or maneuvering in a terminal area. Aircraft operators have shown a reluctance to install a special computer for this service but may find it practical to include the computation in a central computer.

(2) Self-Contained Dead Reckoning—Doppler and Doppler-inertial dead reckoning sensors for ground speed, drift, and directional reference are soon to become operational in many aircraft. A central computer could be programed to achieve a high order of accuracy in the determination of navigation position, course, distance, ground speed, wind component, direction, and distance to go.

Air-to-Air Anticollision

For two aircraft flying straight-line courses, the conditions for a collision are that the bearing or the rate of closure become and for a time remain constant. Whether the bearing, the rate of closure, or both are used in a given anticollision system depends upon the system concept employed. Operational analysts have indicated that the system should work against two or more targets simultaneously so that an aircraft maneuvering to avoid a collision with one aircraft will not collide with another. This latter requirement tends to emphasize the use of time-shared digital computation and fits well into the central digital computer concept discussed herein.

The computer would calculate on all targets within a specified distance range and provide aural alarm and visual guidance indications when the computed solution shows that a hazardous condition has developed. This example involves a number of computations following each other in sequence and requires somewhat more computer capacity than other services listed herein.

The following expressions are typical of this function:
Constant bearing method:

$$d = R^2|\theta'|/-R'$$

where

d = closest point of approach or "miss distance"
R = range of other aircraft
θ = bearing of other aircraft
primes denote time derivatives

Constant radial component of closing velocity:

$$\pm d = (R^2/R')\,(f'd/fd)$$

where fd = Doppler frequency.

Approach and Landing

Deviation, rate, and rate/rate information has long been a part of the approach and landing phase for both manually used integrated instrumentation systems and automatic flight control. These factors have been used with respect to gravitational forces, atmospheric pressure, earth's magnetic field,[5] and radio-beam patterns of the ILS localizer and glide slope.

The central computer and associated sensors can perform in a way which refines these results and takes into consideration their interrelationships. Temperature and humidity effects can be related to air-pressure measurements. Doppler ground speed and drift can be employed to improve heading control over that available from radio-beam depth of modulation differences and heading reference instruments. As another of the computer functions, Doppler can also be employed to aid in control along the glide slope beam in the vertical plane.

Precautionary and Emergency Features

If the pilot should attempt to lower the landing gear or, in some aircraft, turn on the landing lights when the aircraft velocity is too high, the computer can provide a suitable warning. In a similar way, if the pilot should attempt to jettison fuel at a speed below the placarded value, the computer can provide a warning.

Computation of V_{s_0} or minimum safe speed was previously mentioned. This has special importance in the landing configuration and may be supplemented by a check-list type of information from the computer system. For instance, if the temperature is below a certain value, the computer may call for certain precautions such as cowl flaps closed, heat when the temperature is in the icing range ($-5°$ to $+15°$C.), and carburetor heat if take-off should begin with the temperature $-23°$C. or less.

Many other check-list and precautionary features could be included. Questions of justification and effect on the overall system economics and complexity must be carefully judged to avoid the inclusion of marginal requirements, especially where they might react unfavorably against operationally more important factors in the overall system design.

Conclusions

There are a number of special-purpose computers being installed in new transport aircraft, and there are many more being planned for installation. A point of diminishing returns can develop beyond which a properly engineered central digital computer system will be more appropriate.

The central computer system will decrease the routine cockpit workload and can prove to be invaluable to the pilot under emergency conditions.

Appendix I—Precomputation of Take-Off Performance: Range and Endurance

Aircraft Location

On ramp

Active Inputs

Air temperature
Air pressure
Fuel weight, Passenger weight, Cargo weight } Weight A

Stored Inputs

Aircraft performance characteristics
Company operating criteria
Flight plan
Aircraft net weight—Weight B

Outputs

Speed V_1, V_2, and V_{s_0}, with accountability for temperature and pressure altitude of the airport
Height at end of runway over run area with accountability as above
Available range at flight plan speed (miles)
Available endurance at flight plan speed (hours)

Appendix II—Take-Off Performance Including Emergency Procedures

Aircraft Regime

Take-off and climb out

Active Inputs

Air temperature
Barometric pressure
Air speed
Angle of attack
Acceleration

Stored Inputs

Aircraft performance characteristics
Company operating criteria
Active flight plan
Gross weight
Outputs
True altitude, true air speed
Required thrust indicated in relation to actual thrust
Margin of clearance above minima
Indication of emergency procedures in case of inadequate thrust or loss of power from one or more power plants

Appendix III—En Route Navigation and Anticollision

Aircraft Regime

Climb, en route navigation (air traffic status and anticollision)

Active Inputs

Air temperature, air speed
Barometric altitude
Doppler navigation
Inertial and heading reference
Proximity warning sensors

Stored Inputs

Aircraft performance characteristics
Company operating criteria
Active flight plan
Computed overall weight

(*Continued on page 102*)

ELECTRONICS IN AVIATION

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Component Developments Influencing Aviation Electronics

The status of present and future electronic components which feature reliability, small size and weight, low power consumption, and operation at elevated temperatures is discussed, and the possibilities inherent in a new form of microwave amplifier—the MASER—are suggested.

Introduction

This paper might more correctly be entitled "The Influence of Aviation Electronics on Component Developments." In many instances, the needs of aviation electronics have instigated some of the advances in component design. The most striking example of this is the case of high-performance—and hence high skin temperature—aircraft, which has influenced the design of components for operation at higher and higher temperatures. Such application of components requires the utmost in performance in terms of reliability, small size, light weight, and low power consumption. These latter requirements have been the subject of many articles over the past several years and will not be discussed in any detail in this paper. It is sufficient to point out that the solid-state devices with which we will concern ourselves have led to some of the greatest improvements in these fields of performance requirements.

High-Temperature Operation of Transistors

Let us turn our attention to the extremes of temperature, altitude, and acceleration encountered in aviation electronics. To begin with, what sort of temperatures are generated by high-performance aircraft? Fig. 1 shows the skin temperature as a function of speed for various altitudes. It can be seen that, as the performance of the aircraft increases, the temperatures to which the skin of the air frame is subjected increase very rapidly.

Although there has been a great deal of discussion of the need for air conditioning, it is also obvious that there will be less power demand from the aircraft engines if a minimum of space must be air conditioned, such as for the crewmen alone. In this case, the electronic equipment, and hence its components, must be capable of operation at temperatures as high as the skin temperature. There is a great deal of work now being done to make this possible. We know, for example, that high-temperature silicone resins and ceramic coatings for wire insulation, as well as potting material for transformers, are being developed for use at elevated temperatures.

We have all heard of work in the field of high dielectric ceramics for capacitors so that the capacitor elements in the circuits can also operate under these conditions. More recently, work has begun on ceramic vacuum tubes capable of withstanding temperatures up to 500°C. However, in these areas, there is much to be done. In place of the few specialized ceramic tubes that have been announced, a whole family must be designed and put into production. In the case of capacitors, more work must be done to obtain capaci-

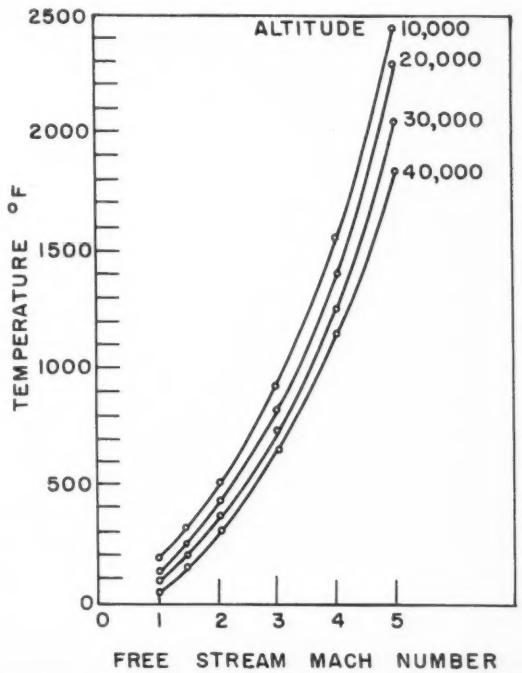

Fig. 1. Skin temperature of a 30° cone as a function of Mach Number and altitude.

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* Research Division.

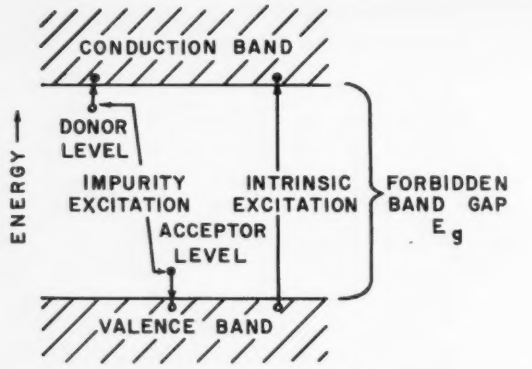

FIG. 2. Schematic energy level diagram for a semiconductor with impurities.

tors of a wide variety of usages. For example, ceramic capacitors rated at only 50 volts or less, for use in low voltage circuits and in transistorized circuits, would mean a tremendous saving in space and weight over those now available. Such capacitors imply ceramic or other high-temperature resistant inorganic materials with thicknesses of the order of 1/10,000 in. Glass sheet condensers of this type are now in the laboratory stage of development.

Having mentioned transistors, we immediately see a need for a considerable amount of work. While silicon transistors approaching 200°C. operation have been made and are available today, this is not a solution to the problem presented by very high performance aircraft. In an effort to solve this problem, industry and the military have under investigation a large number of different materials which show promise of operation at high temperatures.

Table 1 lists several of the materials now being studied and the maximum temperatures at which their bulk properties might allow them to operate as transistors. At this point, it should be noted that the maximum operating temperature for any device is determined by the temperature at which:

(1) Some of the device parameters cause the given circuit to become unstable.

(2) Thermal conversion due to defects or rapidly diffusing impurities takes place in the bulk material.

(3) Evaporation of one of the constituents from the bulk material occurs.

(4) The bulk material no longer behaves as a semiconductor—i.e., becomes intrinsic.

(5) The semiconductor surface becomes unstable.

Of these conditions, the basic limitation is set by (4). A brief explanation of the mechanism involved in this condition is based on the energy level diagram of Fig. 2. An idealized semiconductor crystal may be described by such a diagram, where three energy "bands" are denoted: the valence band (filled with electrons at zero absolute temperature); the conduction band (empty of electrons at zero absolute temperature); and the gap between them, with energies whose occupancy is forbidden at any temperature. In practice, semiconductor crystals always contain impurity atoms, and/or crystal lattice imperfections, which introduce localized energy levels often lying within the forbidden band gap. Such foreign atoms or imperfections may be residual or deliberately introduced. The role of these localized levels as current carriers in semiconductors will be referred to in a later section of this paper. For the present, we are interested in the excitation of an electron from a state in the valence band to one in the conduction band. Each such "intrinsic" excitation produces not only one free electron but also one free "hole," which may be thought of as the absence of an electron in the sea of valence band electrons. These excitations may be produced either by absorption of thermal energy from the crystal lattice or by absorption of photons of radiation of appropriate energy.

For a given semiconductor, the number n_i of intrinsic carriers (electrons or holes, since they are equal in number) is an exponential function of the ratio of energy gap to absolute temperature T. When the temperature has reached a value such that n_i is large enough to correspond to condition (4), we might well select that T as the "maximum temperature of transistor operation." In fact, we have done this in Table 1.

The values of band gap in the table are taken from the literature. It is interesting to note the extremely strong dependence of n_i, and hence maximum temperature, on band gap. At 250°C., the ratio of n_i for silicon to that for gallium phosphide is about 10^6. It can be seen that there is a large field of investigation here which must be thoroughly explored before the most suitable materials can be determined. However, one must be careful in choosing such a material without first considering its effect on other parameters such as frequency performance.

High-Frequency Operation of Transistors

Fig. 3 shows a relative frequency figure of merit as a function of temperature and band gap of the semiconductor in question. This figure of merit is represented by the geometric mean of the electron and hole mobilities, μ_n and μ_p, respectively. The mobility of either carrier is defined as the ratio of the drift velocity of the carrier under the influence of an applied electric field to that field. The maximum frequency of oscilla-

TABLE 1
Semiconductors for High-Temperature Operation

	Forbidden Band Gap (Electron Volts)	Maximum Temperature of Transistor Operation Set by Condition (4) (°C.)
Silicon carbide (SiC)	3.3	1,300
Gallium phosphide (GaP)	2.4	870
Cadmium sulphide (CdS)	2.4	870
Zinc telluride (ZnTe)	2.2	780
Aluminum antimonide (AlSb)	1.6	500
Gallium arsenide (GaAs)	1.4	400
Silicon (Si)	1.1	250

tion of a transistor of given geometry and construction fabricated from the material in question is directly proportional to $\sqrt{\mu_n \mu_p}$. We may thus note from Fig. 3 that—for example—a transistor capable of operation at 200 mc., when made of germanium, would theoretically give equivalent performance at 500 mc. when constructed of indium antimonide but would degrade to 50 mc. if constructed of silicon.

A study of Fig. 3 might lead to a conclusion that high-temperature performance seems to imply a decrease of available operating frequencies. The fact that materials of large energy gap have low values of $\sqrt{\mu_n \mu_p}$, and conversely, forces a serious compromise upon the transistor development engineer since he must invariably suffer degradation of frequency performance to obtain high-temperature operation. Therefore, it is not desirable to try to investigate transistors capable of operating at, say, 1,000°C. for use in aircraft in which the ambient will be only 500°C.

It can be seen that a variety of materials may be chosen for operation up to 800°C. Examples are zinc telluride, cadmium sulphide, and gallium phosphide. All of these materials present problems over and above those simply due to their semiconducting properties. For example, all of these compounds have volatile components, and it may prove in practice that operation at 500°C. will involve a gradual deterioration of the compound by the loss of its most volatile component [condition (3)]. Of even more critical consideration is the problem which already confronts us in the case of silicon transistors. The bulk properties of silicon and the alloys used in conjunction with building these transistors are such that operation should be feasible up to perhaps 250°C. However, surface stability has still not been brought under sufficient control to allow this operation [condition (5)]. Therefore, at even higher temperatures, such as 500°C., the greatest hurdle to be overcome might prove to be that of surface stability

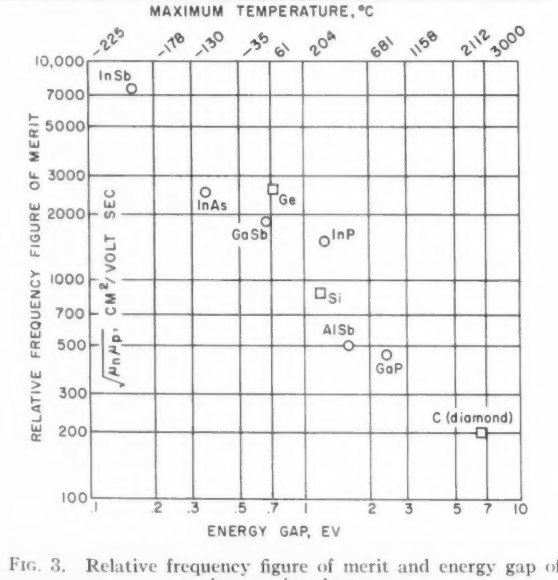

FIG. 3. Relative frequency figure of merit and energy gap of various semiconductors.

and hence transistor reliability. Interestingly enough, diamond would appear to be the only elemental semiconductor available which could be used to operate at these temperatures and even above. However, we are all aware of the problems confronting us in the technology of artificially grown diamonds. At this point, it should be emphasized that, although there is a tremendous amount of work being done in this particular field, transistors for use at these temperatures are far from being just around the corner.

The subject of high-frequency, as opposed to high-temperature, operation of transistors deserves greater mention than we have so far given it. Many of us have heard of a few transistors made in the laboratory with frequency responses in the hundreds of megacycles. These will in the foreseeable future become commonplace. However, these units can have at the most a "built-in" potential amounting to a few tenths of a volt between emitter and collector and hence a field of the order of 1,000 volts per cm. The nomenclature used is an apt one; diffusion techniques make possible a distribution of donor and acceptor impurities in the base region which are "built-in" in such a way as to give rise to the so-called drift field. The potential difference leading to this field, which helps carriers to drift from the emitter to the collector, can never exceed a voltage of more than a few tenths of a volt in magnitude.

Another limitation arises from the fact that the base region of a transistor can be made no narrower than about 1/10,000 cm. Below this region, the mean free path of the carrier becomes longer than the width of the base region, and the base can exercise no control over the transistor current flow, and hence amplification cannot occur. It is therefore obvious that, to achieve higher frequencies, higher fields must somehow be applied. We know that in the immediate neighborhood of a *p-n* junction biased in the reverse direction we can have fields as high as a few hundred thousand volts per centimeter before breakdown occurs. By suitable impurity doping, these fields can be made to occur over a distance of a few thousandths up to about 1/10 mm. Although no operative units are known to have been made, experiments regarding the injection and extraction of carriers from these space-charge regions have shown that considerable promise exists for the future and that, within perhaps 5 years, transistors utilizing these principles may well be available. It could be expected that such semiconductive amplifiers might operate over the present microwave frequency band. What their noise characteristics will be, and how much power they can generate, is purely speculative at this time and is unpredictable until further experiments have been carried out.

PHOTOCONDUCTIVE DETECTORS FOR INFRARED RADIATION

The detection of radiation by photoconductive devices is a topic that again involves a consideration of semiconductors and high temperatures. In this case,

however, temperature is our ally since the infrared radiation emanating from the surfaces of high-speed aircraft is a direct result of the high temperatures of those surfaces—wavelengths of this radiation being determined by the temperatures involved. The solution to the detection problem is made easier by information gained in our basic semiconductor research, which has led to new theories and concepts of photoconductivity. Indeed, it should be possible to design photoconductive detectors having the proper wavelength of maximum sensitivity, as well as the desired frequency response for the particular application involved.

Any description of photoconductivity in semiconductors must begin with a discussion of a parameter that has not, as yet, been mentioned—the lifetime of the photon-excited carriers, which are responsible for the photoconductivity. This lifetime is associated with the amount of time the carrier spends in a free state—for example, an electron in the conduction band—before either recombining with its opposite member or becoming immobilized at a trapping center. The recombination process, essentially the reverse of the pair production process, seldom occurs directly but rather through the medium of so-called recombination centers. These centers are bound states in the forbidden band (Fig. 2) which arise from the presence of impurity atoms or crystal imperfections in our otherwise perfect crystal. Under certain conditions, the bound states may instead act as trapping centers. Both types of center can capture carriers, say electrons, but the distinction between them arises from the fact that the recombination center permits the recombination of its captured electron with a hole that is subsequently captured, whereas this process does not occur readily in the trapping center and its electron is lost to the conduction band by thermal excitation. For deep-lying traps (bound states near the center of the forbidden band), a considerable length of time may elapse before this excitation occurs. As a result, if the trapped electron originally resulted from hole-electron pair generation, charge neutrality requirements ensure that the hole remain present to contribute to photoconductivity for this prolonged time. In the case of silicon, such deep-lying traps having time constants as long as 10 min. have been observed. The behavior of some of the extremely long lifetime cadmium-sulphide materials, which are commercially available, arises from the presence of such traps.

From our definition of lifetime, it may be seen that trapping centers increase lifetime and hence increase sensitivity; recombination centers decrease lifetime and hence decrease response time. The relative numbers of these types of center can be varied by addition of suitable impurities to the host material. However, as might be suspected by those who are used to thinking in terms of a gain-bandwidth product for amplifiers, there is an approximately constant sensitivity-inverse response product involved when we attempt to increase either parameter in the photoconductors.

With this background, let us examine the list of semiconducting materials with varying energy bandgaps in Table 1. Implied there is a whole range of threshold wavelengths below which hole-electron pairs are generated in the semiconductor and which will lead to photoconductivity. The threshold wavelength of photon excitation of pairs is inversely proportional to the energy gap value; a wavelength of 1.24 microns corresponds to an energy gap of 1.0 ev. Also of interest is the fact that the wavelength at which the maximum energy is radiated by a hot body is directly proportional to the absolute temperature of that body; at 1,000°K. (1,340°F.), the maximum wavelength is 2.9 microns.

Photoconductivity by the photon excitation of hole-electron pairs is limited by the fact that they are also thermally generated within the bulk of the material. To minimize this trouble, such a semiconductive photoconductor must be made in extremely thin sections, just thick enough so that most of the radiation is absorbed within the thickness of the material. This involves materials of about 1 micron to a few microns thick. It is in this thickness range that the film-type photoconductive detectors must be made.

In order to avoid the difficulties associated with the fabrication of film-type devices, we might turn to another mechanism in semiconductors—impurity excitation. One can choose a semiconductor of large bandgap so that there are few thermally excited conducting electrons. The material can then be doped with a specifically added impurity having a very low energy of excitation. This means that these donor or acceptor levels (Fig. 2) lie very close to the conduction or valence band, respectively. The material must then be cooled to a temperature where most of these impurity centers are not excited (un-ionized) so that the electrons or holes are located at the centers themselves. Radiation of sufficient energy to excite electrons from the donor levels to the conduction band or from the valence band to acceptor levels will then be absorbed, leading to impurity photoconductivity. The absorption will not be as strong in this type of photoconductor; therefore, it must be made in considerably thicker sections in order that all the incident light may be absorbed. However, since it has a lower dark conductivity, the per cent change in conductivity still can be very high. The impurity photoconductor is thus quite feasible but suffers from the disadvantage that the very nature of its excitation process (electron or hole production, but not both) makes it impossible to obtain the extremely high sensitivities possible with the nonrecombining-trap type of materials mentioned previously.

It is interesting to note that inherent in all these devices is the fact that the lower the temperature of the radiated body, the lower must be the temperature of the detector in order to have increased sensitivity. Those detectors sensitive to long wavelengths, which arise from cooler bodies, must of necessity be cooled in order to have any appreciable sensitivity; otherwise,

thermally induced carriers will predominate and the fractional change in conductivity will be negligible. This can be a very serious limitation if it requires liquid nitrogen temperatures or below. On the other hand, it is becoming increasingly clear that, as our knowledge of semiconductors increases, we approach the time when we can tailor-make a photoconductive cell to have almost any threshold wavelength of response and, over a limited range, almost any time constant.

Other Environmental Conditions

Before leaving the general subject of semiconductor devices, it might be appropriate to make a few comments on some operational extremes to which these devices might be subjected. The only basic limitation on low-temperature (say −70°C.) operation of transistors would most probably be in the deionization of the donor and acceptor levels. For silicon, where the levels are of the order of several hundredths of an electron volt deep in the forbidden band, this is not too great a problem. However, it is possible that the problem will arise in connection with the materials under investigation for high-temperature use. For photoconductors, we have already seen that low temperatures are an advantage, even a necessity, for optimum performance.

Altitude, vibration, shock, and acceleration effects on semiconductor devices are largely related to details of device fabrication and packaging. The techniques to be used in satisfying these specifications are for the most part well known. Presumably, the production of future devices will involve either present good engineering practices or reasonable extrapolations of them. At any rate, the problems in this field do not appear to loom very large—present solid-state devices are superior to most vacuum tubes in these respects.

Radiation damage to semiconductors (and here we refer to nuclear radiation) is a field in which relatively little design work has been done. At this time, a greater and greater effort is being expended to determine the behavior of semiconductor materials under irradiation of many types and intensities. We know that changes can be expected in the surface, in bulk lifetime, and in carrier concentration, which can be large enough to cause instability or total failure of operation. At present, such effects are not a design consideration, but future suitable design could greatly decrease the effects that might be expected in present semiconductor devices.

Ferrite Materials and Devices

Among the other components under study for higher temperature operation are those involving the whole field of ferrite materials. These range from computer memory cores to microwave nonreciprocal elements. Ferrites, as you may remember, are oxides of various mixed metals with ferromagnetic properties similar to many metallic alloys but with extremely low conductivity.

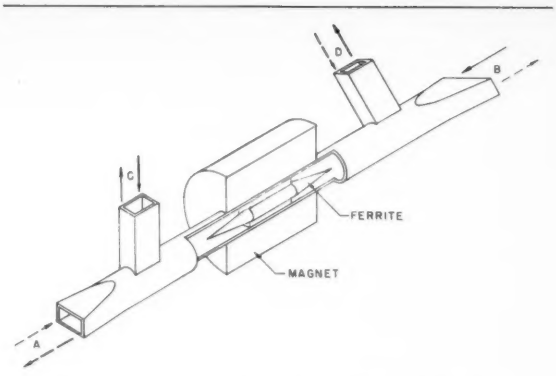

Fig. 4. Cutaway view of a rotation circulator.

One application of ferrites arises from the fact that, as the speed of aircraft increases, it also follows that electronic equipment must do more of the thinking for the people who man the aircraft inasmuch as the time scale of their environment becomes more and more compressed. This implies the use of computer circuits of one type or another, and indeed, aeronautical electronics will see more and more computers of various specialized types being placed in aircraft. The use of ferrite memory cores is rapidly increasing in computers today as their short-term fast read-out memories are far superior to those of conventional magnetic-tape storage units. It is interesting to note that these particular types of ferrites are already being challenged for superiority by another class of material—ferroelectrics, such as barium titanate and lead titanate. These will not be discussed further except to point out that memory elements made of single crystals of these materials appear to offer significant advantages in size and power consumption.

In the ferrite field, perhaps most interesting to airborne electronics people are the properties of ferrites when used in the vicinity of their ferromagnetic resonance. At frequencies above 500 to 1,000 mc. we are able to take advantage of the gyromagnetic effect to make nonreciprocal circuit elements. Such an effect has been known for many years in the optical field—the Faraday effect. Its origin in ferrites stems from the behavior of the material when saturated in a large d.c. magnetic field. If now the material is subjected to a high-frequency electromagnetic field perpendicular to the d.c. magnetic field, the material will present a different effective permeability to the two oppositely rotating circularly polarized magnetic fields into which the high-frequency field may be resolved. This results in different wavelengths of the circularly polarized fields in the ferrite so that the plane of polarization of the traveling plane wave is rotated.

Fig. 4 shows one of the circuit applications of such materials—the circulator. As can be seen, energy entering port A goes out of port B only; energy entering port B goes out of port C only; and so forth. This is

nonreciprocal in that energy flow in one direction follows a different path in the other direction.

The circulator makes possible CW radars similar in design to pulse radar. For example, the generator can be placed at port A, the antenna at port B, and the receiver at port C. Barring reflections from the antenna section, no energy from the transmitter can enter the receiver. Conversely, no energy received at the antenna can be lost down the transmitter but always goes into the receiver. One cannot ignore reflections, of course, and, as we all know, it is possible to destroy the crystal mixer most commonly used in radar by strong reflections, as in the case of the illumination of one antenna by another radar under test. In any case, use of such a ferrite isolator would certainly tend to destroy the mixer. However, by replacing the crystal mixer with a traveling wave tube, which has shown considerable progress in the past few years, one can limit the signal going into the receiver; the traveling wave tube cannot be damaged and can put out only a few milliwatts of power as it saturates. It is only in the last 6 months to a year that traveling wave tubes have been produced with noise figures as low as those obtainable in a crystal mixer. Reference is made to this tube at this point because the use of such a system as described here could lead to greater reliability and flexibility. Certainly, the possibility of eliminating the ATR or TR tube in radar is an attractive one.

The versatility of the type of device shown in Fig. 4 is further demonstrated by considering the result of placing a fixed matched load at port C. With a power amplifier or oscillator connected at port A, it would then be possible to connect a variable load directly at port B since no reaction by the reflected energy from the load can appear at the tube or other amplifying device. The circulator thus becomes an isolator, a valuable addition to the microwave equipment line.

By utilizing the resonance absorption phenomenon in ferrites, one can construct with this material a microwave system which—for example—can propagate a wave in one direction with negligible attenuation, but which almost completely absorbs a wave which is simultaneously traveling in the opposite direction through the system. Here again, the isolator is an obvious application.

The properties of the ferrite at values of d.c. (or low-frequency a.c.) magnetic field below saturation are responsible for another class of device, the phase shifter. This device, which can be made reciprocal, offers the possibility of either amplitude or phase (frequency) modulation of a fixed CW wave.

Numerous other examples of the use of ferrite materials in microwave devices could be cited. The possibility of using ferrite elements in antenna feeds to get electrically, rather than mechanically, scanned beams has been suggested and is typical of the many circuit designs not previously possible.

We conclude our discussion of ferrites with a word about high-temperature operation. In many of the ferrite materials in use today, maximum operational temperatures of the order of 300°C. are the rule. This limitation is set by the Curie temperature of the ferrite, the temperature at which the material loses all its ferromagnetic properties. New families of ferrites, such as the nickel ferrites, with Curie temperatures close to 600°C. are being investigated, and we may expect them not to be inferior in their electrical and magnetic properties to their low-temperature counterparts. In fact, isolators using such materials have been constructed with a 30:1 back-to-front ratio at L band.

The MASER

Even further into the future, but less amenable to time estimates, is the field of the solid-state amplifier, the MASER, which derives its name from "Microwave Amplification by Stimulated Emission of Radiation." Professor C. H. Townes at Columbia University first demonstrated with a beam of ammonia molecules the possibility of this general type of amplification. MASER amplifiers deriving their energies from solids have since been reported.

As we all know, radiation in the electromagnetic spectrum can be caused by transition of an electron from one energy level to another. This is what occurs in a gaseous discharge, such as a sodium vapor lamp. In this case, electrons fall from one orbit to another, and in so doing, release an amount of energy equivalent to the energy difference between the two orbits. In the case under discussion here, much smaller energy differences are involved. As one example, let us consider certain solids where nuclei find themselves in the presence of an extremely strong magnetic field produced by a spinning electron in one of the orbits about the nucleus. The nuclear magnetic dipole can then have two energy levels and in some cases more, which depend upon its orientation with respect to the magnetic field produced by the spinning electron. If by some scheme, and there are many, the material can be temporarily excited into a condition where most of these nuclei find themselves in high energy states and the temperature of the material is such that in equilibrium they would be in a low energy state, there exists an unstable situation in which these nuclei would like to lose energy to return to equilibrium.

It is characteristic of these nuclei that energy differences fall more or less in the microwave range. Obviously, the energy differences can be changed by the application of an external magnetic field, and hence the frequency corresponding to the energy differences can be changed. At such low frequencies (low compared to those of optical radiation), the atom cannot easily emit this radiation spontaneously. However, if one applies a weak electromagnetic field of the proper frequency, radiation is stimulated, the field receives energy from the nuclear states, and amplification results.

Many solid-state and molecular beam approaches to this same technique have been investigated by a

(*Continued on page 98*)

ELECTRONICS IN AVIATION

"Planning for the use of our common airspace in an evolving air traffic - air defense situation will first require a more complete specification of the needs and requirements for air traffic control."

Common or Uncommon Systems: Air Traffic Control and Air Defense†

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Introduction

Our nation's air traffic control and air defense are conducted in a common airspace. Furthermore, both activities are directly concerned with the processing of radar data and flight plans, the generation and display of the air situation, and the control of aircraft. For these reasons, it is frequently suggested that common facilities be used to conduct both air traffic control and air defense, thereby conserving manpower, equipment, and operating costs.

It is extremely tempting to oversimplify a comparison of the two systems, but one must be wary of generalizations. One widely used shibboleth suggests that the basic difference between the two systems is that one attempts to bring aircraft together, while the other attempts to keep them apart. This is an oversimplification. What we actually do in air traffic control is to attempt to bring large numbers of aircraft onto a final approach path with minimum separations. We can say, perhaps, that one of our current air traffic difficulties is an inability to bring aircraft closer together with safety.

In this paper, an attempt is made to describe the essential similarities and differences between the two systems in a more fundamental way and to point out those directions in which further efforts toward a future common system might best be made.

Present and Future Air Defense

It is assumed that the reader is well versed in the current air traffic control system and its procedures. A few words on air defense may be helpful as background.

Our current continental air defense is conducted from Air Defense Direction Centers (ADDC's)—formerly termed GCI or ground-controlled intercept stations—located at long-range radar sites. At these sites, located 100–200 miles apart, radar information is processed to detect and initiate tracks. Large vertical plotting boards are used to provide a pictorial representation of the air situation to all personnel in the center. Intercept Directors, using individual radar scopes, scramble aircraft and vector them by voice radio on appropriate intercept courses. The direction of weapons is coordinated with adjacent Direction Centers and with a higher echelon of Combat Centers.

These Direction Centers receive flight plan information from the CAA's Air Route Traffic Control Centers for all aircraft operating in critical identification zones (the ADIZ). The Direction Centers generally coordinate with the en route centers and airport towers regarding interceptor scrambles, and, in many cases, operating agreements between the Air Force and CAA have resulted in the reservation of corridors or altitudes along certain airways. The Direction Centers provide some flight-following and monitoring assistance to military jet aircraft and frequently assist civil aircraft on request.

The Air Force is installing a new semiautomatic air defense system. Security regulations preclude a discussion of details, schedules, or capacities; however the broad outline of this new system has been discussed in the press. This system—termed the Semi-Automatic Ground Environment or SAGE—involves the collection of data from a number of radars, both long-range and short-range, and the transmission of these data over leased phone-line facilities to semiautomatic Direction Centers. A total of 32 of the centers will cover an extremely large percentage of the area in the continental United States.

In addition to the radar data, all pertinent flight plans, weather data, Ground Observer Corps reports, and other data which can be used for air defense purposes will be transmitted to large, high-speed digital computers located at the Direction Centers. The computers, with assistance from personnel operating with computer-generated console displays, process this

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data to generate an accurate portrayal of the air situation. Coordination with adjacent centers and higher headquarters is performed automatically, while the assignment and direction of weapons is implemented by the man-machine combination using voice radio and data link communication. The nature and extent of the coordination between the Air Route Traffic Control Centers and the SAGE System are essentially the same as with the existing manual system.

SAGE was developed to satisfy *air defense* requirements, and little consideration was given during the design phase to *air traffic* requirements. Nevertheless, SAGE now performs some functions which are similar, if not identical, to those encountered in air traffic control. The primary example is the use of radar data for the tracking of aircraft. Aircraft positions thus tracked by SAGE could be transmitted to an ARTCC for display or other use. Unfortunately, however, current Air Force operational doctrine does not require the tracking of all aircraft of interest to air traffic control. In general, although similarity of functions may seem evident, operational procedures necessitated by Air Force responsibilities will preclude using this capability in a fashion useful to the CAA. Thus, under *current* plans for operational use, SAGE will not materially aid or assist the air traffic problem. High-level discussions between the Air Force and CAA are currently concerned with this problem.

What about the future? Is it possible to combine or integrate more closely the functions of air defense and air traffic control in future semiautomatic systems? Before attempting to answer these questions, it will be necessary to review some of the similarities and differences between the two systems. In this comparison, we shall generally look ahead to the type of higher capacity, en route air traffic system needed for the future.

Similarities Between Air Traffic Control and Air Defense

Superficially, both systems require the collection and processing of large amounts of aircraft movements data, and each involves a large system in which the activities of numerous persons and agencies must be coordinated.

Specifically both must collect data on aircraft movements from a number of diverse sources. In air traffic control there are advocates of the "primary" source of air traffic control information—that is, one source which is relied upon to the exclusion of all others. This should never be a completely acceptable concept to users concerned with a high degree of safety and reliability. Ultimately, the air traffic control system should have a diversity of methods for determining the air situation and for cross checking these to ensure "safe" failures of equipment and systems. A future air traffic control system, in manner similar to SAGE, will digest primary and secondary radar information, air-derived navigational information, flight plan reports, height-finding radar information, and any other sources of positional information. These will be digested into a common coordinate system in which the positions determined by various means will be found to register or will be suspected.

Both systems require positional information which is free from unwanted noise, ground clutter, or weather returns. Both require a high degree of accuracy and as much resolution as is economically practicable. Studies of the data input problem have shown that the amount of data generated by the ATC sources enumerated above will equal or exceed that which is now processed for air defense.

To this knowledge of aircraft positions, both systems add aircraft velocity and identity in order to establish the "air situation." In addition, both desire to display this information at a central location covering a sufficiently large area so that the ratio of control time to handover time is reasonably high. Perhaps fortuitously, the coincidence between air traffic control and air defense is more than functional, with 26 continental air route traffic control centers country-wide and 32 SAGE Direction Centers. In the heavily traveled Northeast area, the coincidence becomes even closer and there is almost a one-to-one relationship between air route traffic control centers and SAGE Direction Centers.

Both systems, in order to accomplish their control function, must make decisions concerning the path which aircraft must fly. While a great divergence exists in end objectives, both have large amounts of quantitative information to store and process. The detailed arithmetic operations which must be performed may be different in each case; but the operations are arithmetic, and, when more than mere arithmetic is needed, then both systems wish to introduce elements of human judgment. Studies have shown that the amount of human intervention—measured in terms of numbers and general character of display and individual access required—and the complexity of logical processing are at least equal to similar processing for air defense under the logical rules currently put forward.

Finally both air traffic control and air defense require that these decisions be communicated to the appropriate aircraft for action.

Differences Between the Systems

In air defense, the ground environment attempts instantaneously to counter the enemy attack, and it must be prepared to monitor the progress of the battle and respond quickly when this is required. The air battle cannot be scheduled since a large number of eventualities and future enemy actions must be expected. The air traffic system is inherently more stable and well ordered, and the control of traffic is predicated on knowledge of aircraft intentions.

In a sense, then, the differences between air defense and air traffic control are those between chaos and order. If the air traffic control system were perfectly

ordered, there would be a relatively small data-processing problem—e.g., an aircraft is given a single clearance from take-off to touch-down and always follows its plan. The amount of data processing increases with disorder—e.g., an aircraft fails to meet its flight plan, causing conflicts which require the rescheduling of other aircraft—reaching a peak in the air defense type of situation. An important question, then, is whether a semiautomatic air traffic control system must cope with total system disorder every fraction of a minute, as is necessary in air defense? To illustrate this difference, at the present time air traffic control data are refreshed on a scale of *minutes* rather than *seconds* as in air defense.

Another difference between the two systems relates to the degree of control over its operation. In air traffic control, the pilot's intentions are known; but in air defense, the enemy's intentions are unknown, and he makes and breaks the rules of the game. In air traffic control, the rules of the game can be set by mutual agreement, and the game is one in which both sides are cooperating toward a mutually desirable goal. Thus, the aircraft operator may be willing to accept some minor constraints if he can be convinced that these will permit him to travel more safely or expeditiously. How far should we go in this direction? Can we segregate the airspace for different categories of users, depending on the air-borne equipment carried? This possibility of airspace segregation—for example, into high-speed and low-speed traffic lanes—illustrates another significant difference between the two systems.

In air defense, one is forced by an uncooperative enemy to monitor actions by means of a ground system which may take several radar scans to identify enemy actions. In air traffic control, a cooperative aircraft can make changes in flight known to the system which will employ this knowledge to affect the control process. To what extent can this knowledge of intentions be used to simplify the air traffic control processing problem?

Future Systems

It is clear from this cursory review of similarities and differences that there are at least as many unresolved questions as there are questions to which answers are now available. Also, as we look to the future, it is evident that an improved semiautomatic air traffic control system could take any of a number of forms, three of the more obvious possibilities being

(1) An entirely new system, independent of SAGE but sharing some data-collection facilities. Such a system could use many of the same military radars as SAGE but would have separate computers and control centers.

(2) A common air defense - air traffic system in which SAGE and its facilities, possibly augmented to handle the increased load, are used to accomplish the joint mission.

(3) A mixed system, possibly using the SAGE centers to execute the air-surveillance and tracking functions but using separate computer facilities at the ARTCC's to perform the unique air traffic functions.

The overlap of data-gathering facilities and data-processing requirements for air traffic and air defense is significant; and, economic considerations being of extreme importance, the general tendency will naturally be toward a common system. One point stands out clearly, however, and that is the lack of a firmer statement of our air traffic control requirements. Until these are known, we cannot decide whether a common system is feasible.

As an initial step, the future air traffic system must be studied as an independent problem so as to indicate clearly the air traffic requirements. If this is not done, an initial common-system study could result in requirements that do not adequately satisfy either air traffic control or air defense.

For the future, however, it is clear that many of the semiautomatic features now being used in air defense should be employed for air traffic control. Some of the advantages of a semiautomatic, large-capacity, system such as might be obtained through use of high-speed digital computers are obvious; other possibilities pertaining to the use of the airspace are less evident. For example, as the demand for air travel increases, one goes beyond the mere "utilization" of airspace and becomes concerned with the *optimum* utilization of this airspace. In order to attain maximum density with adequate safety, it is necessary that the airspace be employed dynamically. It is unreasonable, for example, to allocate the same spatial insulation, known as the ANC separation, to an unequipped aircraft as to a VORTAC-equipped business aircraft of the future. The former is uncertain of his position and, for lack of communications equipment, is unable to take corrective action to maintain a position required by the controller.

Similarly it would be unfortunate to set aside large reservations of airspace for sporadically used Danger Areas. With reliable and rapid communications, it would be possible to ensure safe transit through such areas in unused off-hours. It is also wasteful to set aside large blocks of airspace for permanent departure and arrival zones encompassing all possible ascent and descent characteristics for a variety of aircraft. This is done today because the controller is unable to visualize and compute rapidly enough to ensure complete safety.

All of these matters reflect the need for a dynamic utilization of airspace; this is possible with data-processing machinery which is rapidly responsive to a broad spectrum of operational conditions and multiple classes of aircraft of widely differing performance.

The response of such systems includes both short-term and long-term characteristics. One would like to have a system which does not become obsolescent with the advent of new aircraft or with the advent of aircraft of substantially different performance characteristics. Ideally as the STOL aircraft become operationally active, one would like to introduce these

into the air traffic control system by simply writing a new Standard Operating Procedure rather than buying a new piece of machinery. The short-term response of the system is equally important. It should be possible to operate aircraft of widely differing characteristics in the same general volume of airspace.

Common Use of Radar, Beacon, and Radio Facilities

There are three areas in which more immediate consideration can be given to common facilities for common use of the airspace—in this case, the electromagnetic airspace as contrasted to the volumetric airspace.

Both air traffic control and air defense systems desire to see all aircraft in the airspace. It seems unreasonable and uneconomic to superimpose two radar networks—one for each system. In addition to the doubled initial outlay for a duplicate network, there are even more pressing considerations of annual maintenance costs, the finding of the technically trained manpower to service a dual network, and obsolescence.

Furthermore, the allocations of frequency spectrum for radar purposes are limited, and it would be wasteful to use this irreplaceable national resource wantonly. While the interference between radars can be minimized by various palliatives, there is always some price in dollars or performance which is paid.

It therefore seems essential that the air defense function and the air traffic control function share a common detection network. In the past there have been technical and economic limitations which have precluded such sharing—namely, the bandwidths required to transmit radar data have required prohibitively expensive communications facilities except over extremely short distances. Bandwidth compression schemes to feed radar data into a central computer are now available to remote the same radar pictures to other users. The economic importance of this development can hardly be underestimated in the face of a new radar network for air traffic control. For example, in the New York area, the information of *three* radars which normally feed a SAGE computer can be remoted to the Idlewild Center for one third of the installation cost of a *single* new radar in New York. The annual operating cost of the two alternatives (excluding obsolescence costs) are comparable, while the technical manpower requirements are substantially less for the remoted data.

Equally pressing problems exist in the field of beaconry. Studies by the CAA Technical Development Center, the Airborne Instruments Laboratory, and others on the multiple interrogator problems are well known. These warrant critical study of any proposal to increase the number of interrogators for air traffic control purposes and particularly suggest the common use of existing interrogator stations. No adequate studies have yet been made of the common system effects on the radar safety beacon when used in a combined air defense - air traffic control environment. The subject of beaconry is so extensive that it is impossible to do justice to it in this short space. Suffice it to say that the proposed beacon system for air traffic control appears to have a very limited operational life in face of the demands that are likely to be made on it. It is difficult to refrain from recommending that the military and civil abandon the present beacon concepts and rethink the entire problem.

Lastly, in the field of communications, the Air Defense Command ground-to-air radio network, sited for defense purposes, provides coverage at an altitude commensurate with the majority of needs of air traffic control. This facility was planned to give control capabilities for large numbers of aircraft both by voice and automatic data link. The major costs for this network lie in the annual rental of communication circuits to remote the radios to central control points. These facilities must be designed for maximum control capabilities during battle conditions, and during peacetime they must, perforce, remain idle. It seems wasteful not to make this communications potential available for air traffic control.

Conclusion

To summarize:

(a) Planning for the use of our common airspace in an evolving air traffic - air defense situation will first require a more complete specification of the needs and requirements for air traffic control.

(b) Optimum use of the airspace, as well as other reasons relating to increased system capacity, point toward a semiautomatic traffic control system for the future.

(c) The relationship of this system with the air defense system may take a number of forms; it is not possible on the basis of present information to state firmly that a common ground control facility will be feasible.

(d) Common use of radar, beacon, and ground-air communication facilities is now technically feasible, economically desirable, and operationally important.

▲ ▲ ▲

A giant task has been assigned the Lilliputian ball to be tossed into space by Earth during the 18-month International Geophysical "Year" beginning July 1. The satellite will be a spherical body of about 21 lbs. and 20-in. diameter. It will contain a radio transmitter operating up to several weeks in the 108-mc. range, with a power level somewhere between 10 and 100 milliwatts. This radiation will serve to permit radio tracking. During short periods the power, provided by chemical batteries, may be increased to permit transmission of data to the ground.

Role of the Earth Satellite in Four Important IGY Experiments†

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Introduction

A meeting of many of the scientists in the United States having experience or interest in upper atmosphere rocket research was held early in 1956. More than 30 papers were presented, proposing various experiments which might be accomplished using a small satellite. A working Group on Internal Instrumentation headed by Dr. James Van Allen was established by the Technical Panel to provide a focal point for evaluating these and other possibilities which might be suggested at a later date. Out of the work of this Group has come a selection of four "hard core" experiments which currently have top priority for the IGY satellite program. These four experiments, selected on the basis of relative simplicity, state of development of the proposed instrumentation, importance of the expected results in illuminating some broad field of science, ease of interpreting the results, and competence or experience of the proposing agency, consist of the following:

(A) An Experiment to Measure the Ultraviolet Radiation From the Sun at Approximately 1,216 Angstroms

This wavelength, known as the Lyman alpha line, is emitted by hydrogen and represents a large part of the total ultraviolet radiation received from the sun. The experimental equipment consists of the tiny ionization chamber shown in Fig. 1, filled with nitric oxide gas. This gas begins to ionize at about 1,340 angstroms. The lithium fluoride window used in this cell, however, will not transmit wavelengths shorter than 1,100 angstroms. Thus, the cell responds only to the narrow band of ultraviolet between 1,100 and 1,340 angstroms. Inasmuch as the solar radiation spectrum contains no other important elements within this band, the cell effectively measures the Lyman alpha radiation. Simple circuitry shown in Fig. 2 "remembers" the peak value from each orbit around the earth and transmits these data together with a short period of continuous observations via radio telemetry whenever the satellite passes over a receiving station. The equipment is a development of the Naval Research Laboratory which has been assigned overall responsibility for this experiment.

Solar ultraviolet and X-radiation, which are believed to be related to each other, contribute most of the energy which is absorbed in the upper atmosphere. This absorbed energy appears first as ionization, affecting long-distance, point-to-point radio transmission on the surface of the earth and causing other interesting phe-

U.S. Naval Research Laboratory Photo

Fig. 1. Photocell for measurement of Lyman alpha radiation.

† The Review is indebted to Dr. Porter for his permission and assistance in accenting this portion of his paper, "Current Status of the U.S. Earth Satellite Program for the International Geophysical Year," presented at the IGY Earth Satellite Session, 25th Annual Meeting, IAS, N.Y., Jan. 28-31, 1957.

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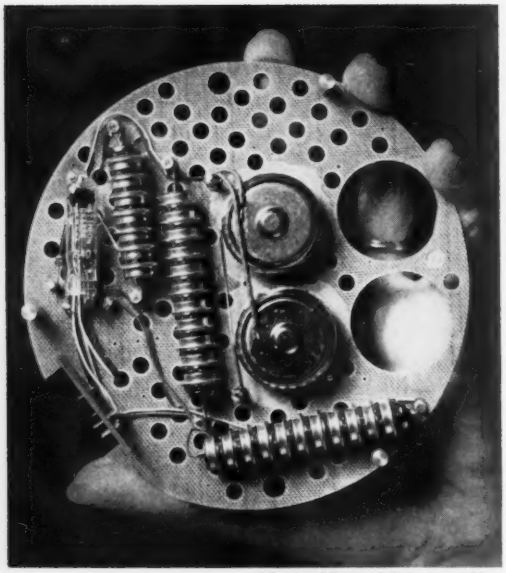
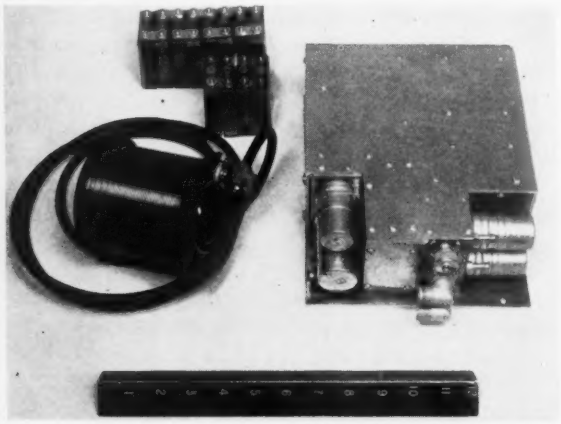


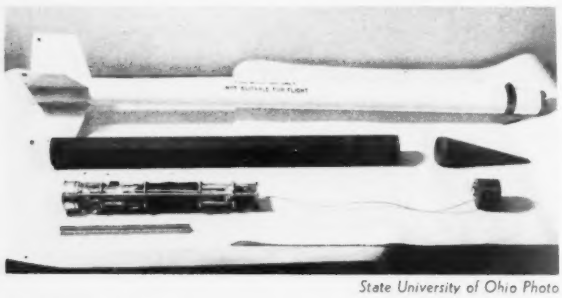
U.S. Naval Research Laboratory Photo

FIG. 2. Circuitry for Lyman alpha radiation experiment.



U.S. Naval Research Laboratory Photo

FIG. 3. Basic elements of proton-precession magnetometer.



State University of Ohio Photo

FIG. 4. Proton-precession magnetometer as packaged for use in a balloon-launched rocket.

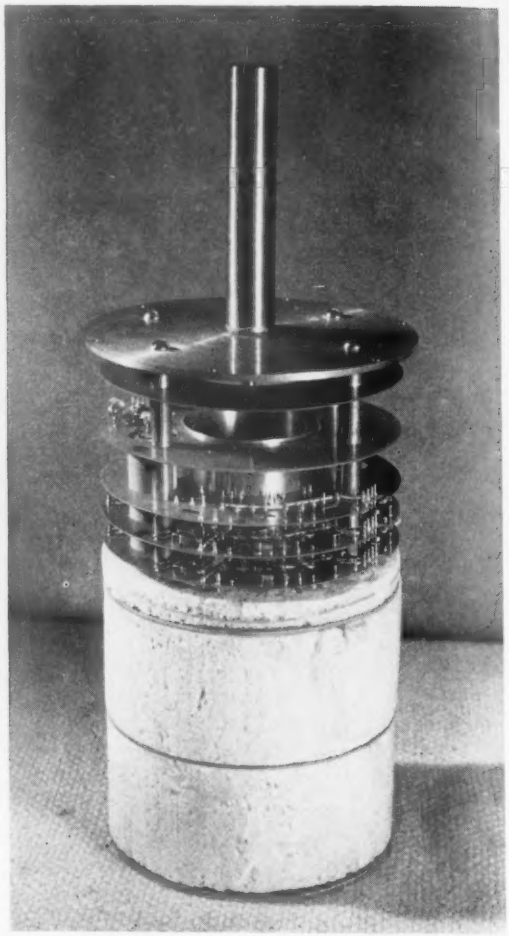


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FIG. 5. Instrument package for cosmic ray experiment. The tube at the top is a Geiger counter.

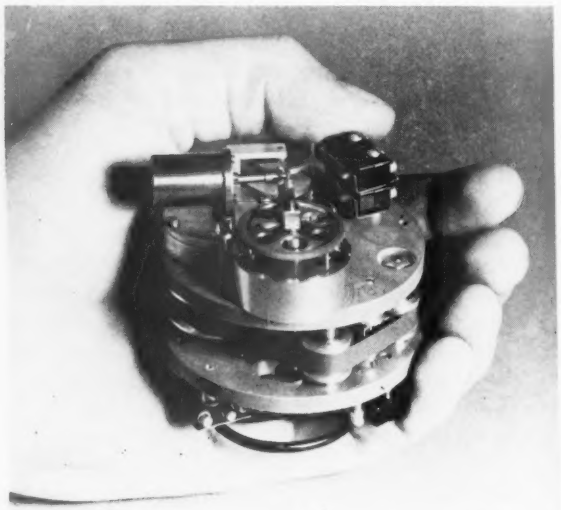

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FIG. 6. Miniature magnetic tape recorder for cosmic ray and energy balance experiments.

nomena such as glow of the night sky. Eventually part of this energy finds its way to lower levels in the atmosphere by mechanisms that are not fully understood, where it undoubtedly influences the weather and cli-

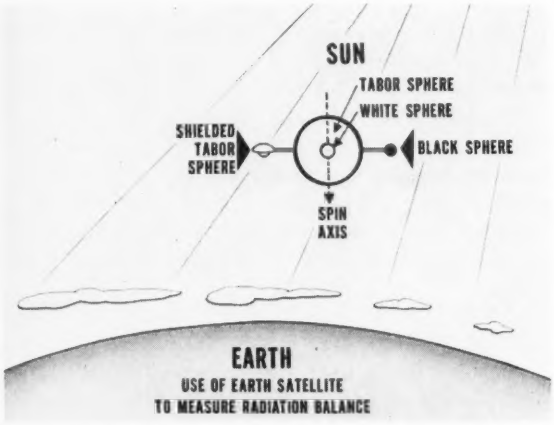


FIG. 7. Use of the earth satellite to measure radiation balance.

mate. It would be useful to have this solar ultraviolet data for any 2-week period, but if the period of the experiment should happen to include a solar flare or some other abrupt disturbance, the data would be of the greatest possible scientific interest. You may recall that the period of the IGY was selected as a time when the probability of such occurrences would be high.

(B) An Experiment to Measure the Earth's Magnetic Field

It is generally believed that there are two components of the earth's magnetic field—one which is constant or at least changes very slowly and is associated with the solid body of the earth itself, and the other which changes rapidly and is created by the motion of electrical charges in the upper levels of the atmosphere at distances ranging out to several earth's radii. The satellite can obtain synoptic data covering a large part of the earth's surface every day. Furthermore, it will sample a wide range of altitudes, in the very interesting range between 200 and 1,200 miles.

Instrumentation of extreme precision is needed for the data to be of any real significance since the scientist in this case is looking for relatively small variations compared with the steady-state value. The type of instrument which has been selected is known as the proton precession magnetometer. As the name suggests, its operation depends on the fact that protons have both angular momentum and magnetic moment. If a number of protons are aligned in the same direction —for example, by means of a powerful electromagnet— and then released, they will precess in the earth's magnetic field at a rate which is determined only by the scalar value of that field. This rate will be measured by pickup coils and transmitted directly to the ground by radio telemetry. The magnetometer will be constructed by Varian Associates under the supervision of its inventor, Dr. Packard, but the overall responsibility for the experiment and for analysis of the data will be in the hands of the Naval Research Laboratory. The basic elements are shown in Fig. 3. A similar instrument designed for use in high-altitude rocket flights is shown in Fig. 4.

Inasmuch as so-called magnetic "storms" affect both communications and transportation, any information that will increase man's understanding of their cause and enable their prediction would have a very practical value. However, to the scientist the significance of these measurements will lie in their ability to test the various hypotheses which have been made about streams of charged particles in the upper atmosphere and to provide the clues needed for more sophisticated hypothesizing.

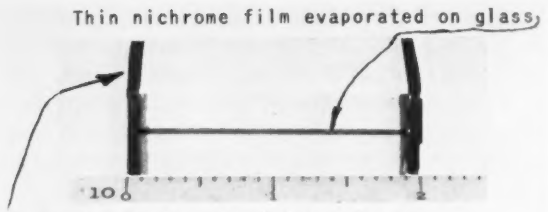
(C) A Cosmic Ray Experiment

The nature and origin of the "stripped-down" high-speed particles known as cosmic rays is not well known, nor is it easy to make measurements of their characteristics because some of these primary particles interact with the atmosphere to create secondary particles which obscure the effects it is desired to measure. In the IGY satellite experiment, a Geiger counter will be used to measure the total incidence of cosmic rays at levels well above the atmosphere, without respect to charge, energy, or direction. The basic counter, shown in Fig. 5, is contained in a $5^1/_2$-in. package, consisting mostly of batteries surrounded by foam insulation. A miniaturized magnetic tape recorder is also included in this experiment, Fig. 6, so that the data taken during the complete 90-min. trip around the orbit can be played back in a few minutes while the satellite is within range of a receiving station. All of this equipment has been developed by the Physics Department at the State University of Iowa, which will have the overall responsibility for this experiment.

It is undoubtedly too early yet to know what the practical significance will be of cosmic ray information obtained in this way. Although more elaborate instrumentation and a different orbit would indeed be desirable and should certainly be considered for any future program, the presently planned experiment which will result in reliable synoptic data over more than half the earth's surface every day for 2 weeks will be an exceedingly valuable first step. The fact that it will be done in close cooperation with upper atmosphere "sounding" rocket tests and other related scientific measurements in the IGY will, of course, considerably enhance the value of the results.

(D) An Experiment to Measure the Terrestrial Energy Balance

Terrestrial energy balance may be defined as the energy received from and given off by the earth to its environment. The principal energy input to the earth consists of radiation received from a particular direction—for example, from the sun. Some of this radiation is diffusely reflected by clouds, the remainder is



U.S. Naval Research Laboratory Photo

FIG. 8. Resistance-strip erosion gage to determine the amount of wear on satellite caused by micrometeorites (2 gages on a pole; 2 on the equator). Assembly tested to 200°C.

converted to heat and is ultimately reradiated as diffuse radiation in the far infrared portion of the spectrum. For this purpose, a configuration of four bolometers similar to that shown in Fig. 7 will be used. Three of the bolometers will be spherical in shape. One will be coated with a material that is black (emissive) at all wavelengths, one will have a coating which is white (reflective) in the visible but very nearly black in the infrared, and one will have a special coating developed by Dr. H. Tabor that is nearly black in the visible portion of the spectrum but highly reflective in the far infrared. The fourth bolometer will have a special shape which will cause it to respond differently to the diffuse radiation from the earth than to the directional radiation from the sun. The four equilibrium temperatures from these four bolometers will be recorded on magnetic tape at approximately 180 points on each orbit and transmitted by radio telemetry whenever the satellite passes over a receiving station. Thus, four equations can be written for successive points about 150 miles apart which can be solved for the three unknown components of energy. This method was proposed by Dr. V. E. Suomi of the University of Wisconsin who will be responsible for the experiment and by Dr. Harry Wexler, U.S. Weather Bureau, who will assist in interpreting the data.

Inasmuch as the awe-inspiring phenomenon known as "weather" is really a thermal engine which receives its heat input from the sun and exhausts by radiation to space, a better knowledge of these inputs and outputs would seem to be the most fundamental data one could expect to obtain. It is believed that the sensitivity will be such that movement of the large-scale air masses which are responsible for meridianal transport of energy can be detected. This technique may therefore be of considerable value in long-range hurricane prediction.

In addition to the four "hard core" experiments listed above, a number of secondary environmental experiments are being planned for inclusion along with one or more of the primary experiments. These will include pressurized chambers with pressure switches to give at least a rough indication of leakage rate in case there should be a puncture by a meteorite, exposed resistance strips similar to that shown in Fig. 8, and also other methods to measure surface erosion by micrometeorites and gas molecules, a microphone and counter to record the number of encounters with micrometeorites above a certain minimum energy level, thermistors for measuring skin and internal temperatures, and so on.

Experiments Which Do Not Depend on Internal Instrumentation

The position of the satellite will be observed both by means of precision radio equipment and by highly accurate phototelescopes. Much scientific value will accrue solely from these position measurements, entirely aside from any internal instrumentation. For example, once the trajectory is established, the location of any point on the earth's surface can be measured with an accuracy almost equivalent to a chain and transit survey by observations of the satellite made from that point.

It is well known that the earth is not a perfect symmetrical sphere but rather an oblate spheroid, shorter from pole to pole than along an equatorial diameter. Thus, its mass must be represented, not as a single point but rather as a point and a ring. For this reason, any satellite orbit other than a polar or equatorial orbit will precess. This so-called "recession of the nodes" will have a period of about 2 months for the 35-deg. orbit. Another perturbation having a much longer period is the rotation of the line through the apogee and perigee in the plane of the orbit, which is referred to as the motion of the line of apsides. If these perturbations can be observed over a long enough time, they will provide a more accurate measure of the oblateness of the earth than any method currently available.

Still other perturbations, notably the gradual change in the height at perigee and apogee, will provide a measure of air density, principally in the region of the perigee. Since no other means is currently available for making accurate measurements of air density at these altitudes, the satellite should improve the accuracy of existing information by at least an order of magnitude. There is also a plan under consideration to release a larger, very lightweight inflatable sphere made of plastic and aluminum foil at some point in the satellite orbit. Because of its higher drag to weight ratio, such a sphere would make it possible to obtain more accurate data in much shorter periods of observation.

The radio direction measurements at 108 mc. will be subject to angular errors which will be a function of the integrated ion density along the path of the radio transmission and the zenith angle of that path. If the orbit is well known and radio measurements are taken over a wide arc, including some relatively large and some relatively low zenith angles, it should be possible to compute a value of integrated ion density at each satellite passing over a radio direction-finding station. These data, together with information about the structure of the ionosphere which will be obtained by other means, should be of extensive value in ionosphere research.

Status of the Program

It is, of course, difficult to write about the status of this fast-moving program. It may be said in summary

at this time, however, that the organization of the program is complete; designs have been frozen for the satellite, its boosters, and the instrumented experiments, as well as for the optical and radio tracking networks; procurement is about on schedule with one or two exceptions; and the test firing program has begun. Based on the relatively complete design data now available, it appears that the performance will be at least as good as planned and that an impressive series of scientific experiments can be carried out using these vehicles.

▲ ▲ ▲

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IAS Twenty-Sixth Annual Meeting

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ELECTRONICS IN AVIATION

Howard K. Morgan*
Bendix Aviation Corporation

Common System Standards

The necessity for the adoption of standards to guide development and lead to the abolishment of the black box.

Introduction

By the Common System, we mean a system whose elements have never been officially recognized. It is certainly contemplated by the industry as a whole that Mr. Curtis will be instrumental in the establishment of a body that will make the elements of the Common System an official pronouncement. Certainly all of us look forward to that day.

But when we have arrived at the point where the Common System has had its elements firmly recognized, with the necessary official revisions as the state of the industry grows and progresses, then we shall need standards.

The air traffic control, communications, and navigation subsystems of the Common System are interrelated naturally, but some of the air traffic control elements can be taken as more specific examples.

The four parts of the air traffic control subsystem come under the following headings:

(1) *Flight Plans*—An important standard is the method of naming the route and the altitude.

(2) *Reporting*—An important standard is the technique of transmission of information.

(3) *Signaling*—An important standard relates to the kind of signal which gives permissive indications to the pilot.

(4) *Surveillance*—While the operation of the ground radar equipments is important, a common standard is needed for the transponder beacon, for example.

Flight Plan

The flight plan must be transmitted in whole or in part down the route of the flight prior to its departure. While the flight plan may show essential position fixes and altitudes in plain English, this is hardly suitable for use in computers. True, the information may be sent by teletype; but, if it is ever to be compared with flight reports, the spoken word of the flight report and the name of the town must both be translated into the common language of a machine.

Presented at the Electronics Session, 25th Annual Meeting, IAS, N.Y., Jan. 28–31, 1957.

* Director of Commercial Aviation Systems.

Reporting

Now let us choose an arbitrary standard of latitude and longitude to the nearest minute as our standard for location of each fix. The pilot might object to using some eight numbers to identify each fix since numbers are hard to remember. He can remember three letters more easily. But a machine can easily be made to turn the letters into latitude and longitude and vice versa if required. A machine to take the spoken word of a flight report and turn it into these letters or latitude and longitude is difficult to devise. Further, there may be no three-letter symbol for certain fixes since a cross-country flight may establish a fix by means of distance and azimuth from some navigation facility.

But let us stick to our tentative standards—latitude and longitude. The flight plan fixes at the point of origin can be either written so directly or translated by machine if this proves more economical or feasible. The report from the aircraft may still be given as a name and translated by a man on the ground either to the three letters—thence through a translator to latitude and longitude—or to the eight figures directly.

But if it is known that the air traffic control automatic computers will always receive latitude and longitude, such machines can then be devised for the task in question to keep track of traffic, establish safe separations, or the like.

However, if we abandon latitude and longitude altogether and give position fixes in azimuth and distance, machines can still be built—but may be more complicated. It is important—which is the point here—to establish some one standard.

Still in relation to the first two points, flight plans and reporting, the determination of altitude standards is important. If the altitude used in flight plans and position reports gives no common reference, the exact altitude of the plane is not known too well. Let us say two aircraft depart over the same route, one eastbound from San Francisco and the other westbound from Denver. One is to cruise at 17,000 ft., and the other at 18,000. If the barometric settings are the same, there is left the error of the particular system in each aircraft. But if the settings are not the same when

they pass, the separation between them is unknown. Here again a standard might be chosen which calls for special setting methods of altimeters along a route which is hardly practical. This is a highly procedural process and could be quite involved.

Let me therefore suggest that we use a standard setting for cruising purposes of 29.92 at all times. I am not suggesting that the pilot avoid obstructions or make landings with such an altimeter, but I am suggesting that all reporting of altitude and establishment of flight elevation be based on the standard setting. Now the automatic equipment for air traffic control has a standard to go by. Altitude separations are reduced to a common language, and the accuracy of the pressure reading on the aircraft with respect to the true ambient pressure can be allowed for in procedures—not in air traffic control automatic machinery.

The two examples of fixes and altitudes are perhaps elementary examples of standards, and one RTCA Special Committee is considering the method of fix determination standards today. However, their conclusions are not binding on anyone until some national body adopts them as a United States standard.

Signaling

Let us turn to signaling, the ATCSS, as another example. Were there a standard of the information that the CAA would make available to the pilot, apparatus could be devised in many forms—at the discretion of the user—to display this best. However, let me suggest a simple standard for purposes of argument only.

Turn to block signal practice if you will. There might be a green, yellow, or red light. But, unlike ground practice, the course of the flight does not proceed over a fixed rail. Thus some display of the point and altitude to which the signal refers is necessary. Now we return to how this can be done. If the latitude, longitude, and altitude were displayed beside the light, its meaning would be evident. Or if you still do not like latitude and longitude, then three or four letters for the fix will do, along with the altitude.

Since the air traffic control signaling system involves both equipment owned by the CAA on the ground and equipment owned by the operator in the aircraft, it might be possible to write a specification for the ground equipment and the air-borne equipment and have these as the standards. If this were done, it would be severely limiting to the design of both ground and air equipment. Each time one of the specifications were changed, its companion would have to be investigated to be sure the two would work together. This, I suggest, is no way to establish a standard. The meeting point common to the two is the signal in space. It is the characteristics of this signal which are of the utmost importance to a standard. The exact character of the signal must be spelled out in detail. This determines coding and decoding methods, and it determines how powerful transmitters must be and how sensitive the receiver must be for the particular user's purpose.

Thus in the air traffic control signaling system we might name the strength and frequency of the signal in space at representative points and the character and sequence of this signal.

In order to determine the necessary characteristics, it is often found that someone will build what he calls a system. Finding his power too low, he raises receiver sensitivity. Finding a special indicator system more to his liking, he adopts an arbitrary code. As the equipment gets into use, its standards therefore become those of what someone did. There are a number of examples of this in our apparatus today.

What I strongly suggest is that a tentative standard be set early in the game which is agreed to tentatively before apparatus is devised which then must be defended against change because of the money invested. If the apparatus is designed by several groups in different ways and they find, in common, some limitation in the tentative standards, then these standards may be revised accordingly before final adoption.

Whereas engineers do not like to be held down by many details imposed upon them by others, they will welcome standards which set the main goal and allow freedom in interpretation in the individual design.

For example, if the ATCSS standards are set with relation to a signal in space, one engineer or specification writer may choose to display these in an entirely novel method. This method may appeal to his customers or to his pilots. Another may choose a wholly different display better suited to his group. Another may use an inexpensive version of a display for his market. But the important thing is that each of these men has a solid standard to determine the signals from which he will derive information.

Surveillance

The matter of surveillance for ATC work consists of at least two main equipments. One of these is the radar element which is wholly self-contained in the ground installation. Possibly such equipment needs only an internal standard in the CAA. But the companion element of the transponder or safety beacon is another matter. Here we have ground and air equipment operating in coordination. While the operator cannot easily modify the size of his aircraft for better radar returns, he can certainly modify his transponder beacon.

Again, as we have been saying, the standard needed is one which defines the signals in space as they relate to the dual interchange of information between air and ground.

For example, I believe that the aircraft response should contain altitude information. A system which might be satisfactory on simple response may be hopelessly inadequate to have this altitude information added at a later time. The early adoption of tenta-

(Continued on page 116)

The operational need and use for an improved navigation capability, freeing the pilot for more important functions.

Self-Contained Navigation Systems

Lt. Col. Robert W. West, USAF

EVER SINCE man first started moving about on the earth, he has been concerned with the problem of not getting lost. It has always been sort of a vague hope that one could move about at will with no other reference than the points of departure and destination. However, the demands for a navigation capability have grown, and there are many factors which must be considered. The advent of the airplane put a great strain on the old-time navigation processes. Weather and long-range flights further added to the problem and demanded rapid improvements in navigation techniques. The use of the airplane, and more recently guided missiles, as instruments of war has made these requirements more severe. The performance characteristics of aircraft have continued to move upward to higher speeds, greater altitudes, and longer ranges creating new demands for a navigation capability to keep pace with these advancements.

It is not the intent of this paper to recommend one specific type of navigation system over another but rather to indicate the characteristics required to provide a navigation capability to meet military requirements. The limitations of present techniques along with the characteristics required to provide an improved capability will be covered, and, where appropriate, reference will be made to benefits which can be provided to commercial aviation.

In considering the requirements for a navigation capability and the type of navigation system needed, much will depend on the mission to be performed. Three logical subgroupings immediately present themselves:

(1) Navigation of tactical or fighter-type aircraft.

(2) Long-range navigation for strategic bomber and reconnaissance aircraft.

(3) Navigation of guided missiles.

Although the nature of each of these fields of military operations is different, there are certain requirements common to all three. The differences to some extent are a matter of degree, and what is applicable in one case may be significantly more or less important in another.

In general, a navigation capability to meet military requirements is needed on a worldwide basis. The navigation system must therefore be capable of guiding the aircraft from one point to another without geographic limitation in daylight or darkness and in all types of weather. It should be reasonably free from jamming and preferably of a type that produces little or no signal which the enemy can detect. An additional characteristic which has become increasingly more important in recent years is the need for automatic features in the system. Beyond this, it must provide flexibility, reliability, and accuracy.

The same factors are applicable to commercial aviation requirements with perhaps less emphasis on the need for security under normal peacetime operations. However, since the air lines will undoubtedly come under the control and use of the Government in the event of war, it is desirable to incorporate this feature in commercial aircraft if possible. Navigation requirements for commercial aviation will closely parallel those of long-range strategic and reconnaissance operations especially when jet-type transport aircraft come into standard use.

There is an urgent need to provide an improved navigation capability to meet the requirements for long-range operations for both military and civilian aircraft and for guided missiles. Ground-based navigation systems are particularly unsuited to meet the needs of either of these programs. The range at which such systems are effective is limited at most to a few hundred miles, and relatively few areas throughout the world are adequately covered. The problem is further complicated in those areas which are covered by a lack of agreement between countries as to which particular system provides the best capability. Consequently there are different systems in different parts of the world with overlapping in some areas and no capability in others, and the user is left with the problem of deciding which type of receiving equipment he should install in his aircraft. Consideration must also be given to the probability that the use of ground-based systems will be restricted in wartime.

Presented at the Self-Contained Air Navigation Systems Session, 25th Annual Meeting, IAS, N.Y., Jan. 28–31, 1957.

* Project Officer, Navigation-Bombing System, Directorate of Requirements, Hq., USAF.

From a military standpoint, one of the serious disadvantages of ground-based navigation systems is the fact that they radiate signals which can be detected by the enemy and used by him for homing purposes. Most significant however is the fact that they can be jammed and therefore do not provide a dependable navigation capability.

It may be argued that many of these limitations can be overcome. However, this would be a formidable task in some instances, and it appears that self-contained navigation systems offer a better means of obtaining the desired navigation capability.

The term *self-contained* is interpreted to mean equipments in which the mechanization is contained solely within the aircraft. This includes systems which employ radiation interaction with the earth and the optical sensing devices used in celestial navigation, as well as the purely inertial system.

The fact that a system is self-contained does not necessarily ensure that it possesses all the characteristics to satisfy our requirements. Dead reckoning and celestial and search radar, three extensively used systems, are all self-contained; however all three have limitations which reduce their effectiveness under certain conditions.

Much of the problem of meeting today's navigation requirements centers around the need for equipment and systems which will provide instantaneous and continuous navigation information automatically. This information should be displayed for the pilot or navigator in easily readable form and should include—as a minimum—present position, accurate aircraft heading, ground speed, and drift. If complexity and weight are not increased out of proportion to the benefits which can be expected, location, distance, and course to destination should also be shown. Higher performance characteristics of aircraft have demanded that decisions be made more accurately and rapidly, and therefore navigation information must be more accurate, current, and readily available. By introducing more automatic features and equipment which will provide up-to-date information, the whole function of navigation is simplified and may allow for reduction in crew complement. The probability of such reductions is perhaps more applicable to transport-type operations than bombing or reconnaissance missions which require other specialized activities in addition to navigating the aircraft. These features are available in the newer developments in the field of self-contained equipments.

The high speeds of today's jet aircraft have exceeded in many instances human capabilities to perform all the functions necessary for flight. Time-consuming arithmetical computations required for manual dead reckoning and celestial techniques provide navigation fix information considerably behind the aircraft position. For example, to obtain a three-star fix requires approximately 12 to 15 min. During this time, the aircraft will have traveled a distance of approximately 100 miles. This distance will increase as we move toward the higher speeds of the future resulting in navigation information which is virtually worthless.

The navigation requirements of tactical or fighter-type aircraft do not include the need for a global capability on any one mission; however the navigation system must provide a capability to navigate within localized areas anywhere around the world. Operations of this type of aircraft are characterized by short time of flight with subsequent reduction in navigation errors which increase with time. Thus, it would appear that dead-reckoning techniques might provide the answer. However, as pointed out earlier, the high speeds along with the requirement to perform other activities leave the pilot insufficient time for manual dead-reckoning navigation. By providing an automatic dead-reckoning computer in conjunction with continuous input of accurate velocity information, quite accurate dead-reckoning navigation can be accomplished automatically, allowing the pilot to devote his attention to other important functions.

There are serious drawbacks to the use of ground-based navigation systems in the short-range or tactical area of military operations in addition to the fact that they are vulnerable to enemy countermeasures. Such systems require extensive surveys for location of transmitter stations, which, when constructed, are subject to enemy action and are a serious deterrent to mobility. There is the further disadvantage that very low altitude operations may be limited either because of the line of sight characteristics of some systems or because signals are affected by terrain features or atmospheric conditions.

Flexibility in the navigation system is of utmost importance in tactical operations because of the requirement for high maneuverability. This may impose restrictions on the type of equipment which can be used.

A further problem which must be kept in mind when installing additional equipments in aircraft of this type is space and weight limitations. Although these are always important considerations in any aircraft, availability of space in fighter-type aircraft is extremely critical, and a few extra pounds impose severe penalties on performance characteristics. Therefore it may be necessary to accept less sophisticated systems of smaller size and weight in the interest of operational performance.

In carrying out long-range operations the problem of providing accurate navigation under all conditions becomes difficult. A single mission or the route of an air line may extend over a wide expanse of latitudes with varying weather conditions and over uncharted land masses and oceans during hours of daylight and darkness. In these global operations, the problem is not one of whether to use ground-based or self-contained systems but rather what type of self-contained system can best supplement existing equipment. Under such conditions there are instances in which accurate fix information cannot be obtained for extended periods. It is necessary then to fill the gap using dead-reckoning procedures which should be as accurate as possible be-

cause of the distances involved. In addition to using an automatic dead-reckoning computer and the input of accurate velocity information mentioned previously, further refinement is possible through the addition of automatic celestial sighting equipment to provide accurate and continuous true heading information. This adds up to providing more precise navigation information and allows a more efficient flight path to be flown. Applied to commercial aviation, this means a saving of time and a consequent reduction of operating costs. It should further make available the development of more effective air traffic control patterns resulting in a safer and more expeditious flow of traffic.

Such a system not only materially improves the accuracy of dead-reckoning navigation but, through the addition of automatic celestial equipment, makes possible additional benefits. The problem of determining accurate true heading information in polar areas is relieved, and the speed and accuracy of celestial fixing is improved. Not to be overlooked is the fact that the workload of the navigator is significantly reduced.

Because of the relatively long periods of time spent over enemy territory in carrying out long-range strategic and reconnaissance missions, there is greater emphasis on the need for navigation systems which are secure. Otherwise the use of the equipment may be denied and the element of surprise sacrificed.

Although the pattern of operations for missions in this area is generally stable, involving few maneuvers, the navigation system must be capable of providing accurate information at either high or low altitudes. Speeds for this type of aircraft have doubled during the past 10 years and will continue to increase in the future, placing greater emphasis on the need for automaticity in deriving navigation information.

As combat weapons, we can say that guided missiles are employed in the same manner as manned aircraft. They may be either short or long range and applied to either tactical or strategic operations. The same qualities and characteristics required for a navigation system in manned aircraft are required for missiles. The problem of providing a guidance capability for missiles is, however, a more difficult task and presents a greater challenge than in the case of manned aircraft. By removing the human element, we have eliminated the power to reason or discriminate, which in the case of manned aircraft may frequently be the deciding factor between success and failure of a mission. It is possible, of course, in short-range missile operations to resort to radio or radar. However, the disadvantages and limitations of using ground-based systems for manned aircraft are equally applicable for missiles. For long-range operations a self-contained system is essential, and, whereas automaticity is a highly desirable feature in the manned aircraft, it is mandatory for missile guidance. The guidance system must be complete within itself, and, since it is completely unattended, reliability becomes an important factor.

Self-contained navigation systems, then, are a necessity if we are to meet all our operational needs. They offer the possibility of providing a more complete navigation capability on a worldwide basis by providing more accurate en route navigation information; they can provide greater security and increased flexibility, and, because they incorporate automatic features, the job can be done more efficiently with considerably less effort.

▲ ▲ ▲

Component Developments Influencing Aviation Electronics *(Continued from page 84)*

large number of laboratories. This device can be built for either narrow or wide-band applications (up to 50 mc.). It also should be inherently capable of approaching theoretical values of noise for the temperatures of the input circuits. We might therefore someday hope to achieve receivers having noise figures very close to zero db., or 8 db. better than present receivers. For similar performance, assuming no interference or jamming, this would imply that 8 db. less power could be used in the transmitter, with a corresponding saving of weight and power requirements. It should also be noted that even lower noise figures are attainable if the input circuits were to be cooled below the ambient. Of interest also is the extreme frequency stability possible from such devices used as oscillators. In this case, frequency stabilities of one part in 10^{10} to one part in 10^{12} could be hoped for. Some devices of this type may find themselves in navigation devices or in secure communication devices based on precise timing.

We have tried to show a few of the high points of present investigations in the field of electronic components and how they will be affected by and will affect aviation electronics. Developments in the solid-state field have been stressed, inasmuch as it is a field in which the authors have been working and a field in which a great deal of promise is seen for the solution of other problems.

ELECTRONICS IN AVIATION

Antenna problems are the concern of both aircraft and electronics designers. Both must consider new antenna problems in early design phases to assure a near-optimum overall system.

Antenna System Problems With High-Speed Aircraft

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Introduction

First, let me state that I consider all components of the radio frequency transmission system from the transmitter or receiver to the radome or antenna cover to be included in the antenna system.

For the purposes of this paper, the relative term "high speed" will not be defined; rather it is intended to point out antenna problem trends with increasing aircraft speeds. It will be apparent in the following discussion that I consider these speeds to be sufficiently high that flush antenna installations generally are required to minimize the aerodynamic penalties to the aircraft.

It is the problems brought on by flush antenna installations that force the structural and electronic designers to cooperate in antenna system design. Of the approximately 15 separate antenna systems on modern commercial aircraft and as many as 35 antenna systems on large military aircraft, only two of these have been selected for examination of the problems brought on by high speed—one in the high-frequency band and the other in the superhigh-frequency band.

The High-Frequency Antenna System

The high-frequency antenna system is that used for long-range communication. The system is for communication by ground and skywave propagation over distances of several hundred to several thousand miles. Transmitter powers up to 1 kw. and frequencies from 2 to 36 mc./sec. are used. Since the aircraft is less than 1/2 wave length long at 2 mc., the antenna problem is one of exciting currents on the entire airplane which then acts as the radiating structure. This has been done externally by the installation of a long wire antenna or a short probe installed from a wing or tail with its axis parallel to the line of flight (see Fig. 1). Another means of exciting the air frame is an isolated tail cap antenna which provides a flush installation using the same voltage feed technique that the probe uses (see Fig. 2). The probe and cap antennas have low resistance and a high reactance with Q's of several hundred at the low end of their band. These impedances are matched by an automatic coupler which resonates the capacitive reactance of the high Q antenna with a high Q coil. This causes very high radio frequency voltages to be developed across the reactance at the antenna feed point. Designs are further complicated by the use of increasingly higher transmitter powers and hence voltages.

The Superhigh-Frequency Antenna System

The SHF antenna system chosen is part of a radar for navigation. In such a system it is desired to transmit a very narrow beam for high resolution of illuminated objects. Considerable accuracy is required to measure beam angle with respect to the aircraft. Such an antenna system is usually composed of a reflector which forms the antenna aperture. It is large in the dimension normal to the plane of the narrow beamwidth. The reflector is installed within the aircraft in a recess behind a dielectric radome which maintains the aircraft contour and withstands the aerodynamic forces of flight (see Fig. 3). Radar trends are directed toward increasingly narrow, high resolution beams. Increasingly larger apertures with smaller angular refractions of the beam by the radome are required.

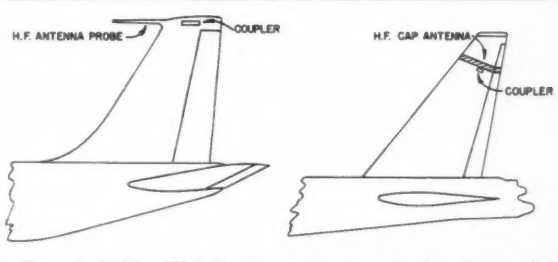

Fig. 1 (*left*). High-frequency antenna probe on vertical stabilizer. Fig. 2 (*right*). High-frequency cap antenna on vertical stabilizer.

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Characteristics of a High-Speed Air Frame

What are the characteristics of a high-speed air frame that bring on antenna system problems, and what are these problems? Some of these characteristics influence all portions of all of the antenna systems, while others influence only individual systems or parts of a single system. The temperature of the aircraft which increases with its speed is a serious problem since it affects both the aircraft and its electronics. Before going further, let us look at Fig. 4 to see just what temperatures we are to expect in the next few years.

Problems and Solutions

As far as antenna system problems are concerned, temperature increase is the greatest influence. It is known that increasing temperature will seriously weaken the structural properties of many of the dielectrics presently used in antenna and radome construction (see Fig. 5). In addition, the electrical properties of some insulating materials, such as dielectric constant and loss factor, also change with increasing temperature in many cases (see Figs. 6 and 7). Just where do these factors become antenna system problems? In the case of the high-frequency communications system, our best present antennas—the isolated cap and the probe—are going to be difficult to sell to those responsible for aircraft structural integrity if present laminates are to be used. These antennas need materials that can replace primary structure and that can be worked with in fabrication. Since the dielectrics also act as feed point electrical insulators, the changes in electrical characteristics—for instance, loss tangent—will reduce the antenna transmission efficiency at high speed (see Fig. 8). A further difficulty will be the more severe voltage breakdown problem which will require greater spacings between antenna conductor and air frame because of the decreased dielectric strength of the air. The overall problem, of course, is that of finding dielectrics that are suitable by both structural and electrical standards.

Another temperature problem is the requirement for cooling the automatic impedance matching high-frequency coupler. The coupler contains electronic circuitry which will not withstand high temperatures. Because of its remote location, it will probably require its own individual cooling unit, causing a weight penalty on the aircraft.

What can be done about these problems? The materials people can continue their progress toward development of the suitable materials that will be structurally sound at elevated temperature and which will have the desired electrical characteristics plus low coefficients of electrical change. Electronic system designers can work toward the development of a coupler with internal circuitry which is able to withstand the environment temperatures.

The structure designers are requested to investigate and familiarize themselves with new and ingenious ways to use and work with dielectric materials. By working with electrical designers, the electrical breakdown of air can be minimized by replacing metal structure around the feed point of the antenna with dielectrics to increase metal-to-metal spacing and reduce the breakdown gradients.

The antenna designer should continue to seek improved means of exciting the aircraft as an antenna. A promising new approach is that of the notch antenna. A notch similar to that shown in Fig. 9 is used to couple currents in the edge of the wing. Advantages of this type of antenna are its nonstructural configuration and the low voltages developed across it. Disadvantages are the difficulty of efficiently transferring power into its very low R and X_L load. This is a problem on which the electronics engineer could make a significant effort.

Next let us examine the SHF or radar antenna system problems brought on by the temperatures of high-speed flight. Recall that changes in dielectric constant and loss factor, as well as the reduced structural strength, occur with increasing temperature. Our problems are largely with the radome which, if it fails at high speed, may cause the loss of the aircraft itself. Structural requirements bring on the problem of heavier walls and excessive weight—a penalty to the aircraft. In addition, reduction of structural strength from high temperature forces mechanical wall designs which are at odds with good electrical design practices. This is brought about because the structural wall will be thicker than the half-wave thick wall at which the radome designer can obtain maximum transmission through the radome.

Even if a half-wave wall could be achieved for, say, low-speed and hence low-temperature operation, it would not be correct for maximum transmission at high speed and temperature due to the changes of dielectric constant and loss factor. We may use Fig. 10 to explain this. Note that the per cent transmission vs. frequency curve is similar to a bandpass curve. Assume that operation is desired at 10,000 mc. for low-temperature flight and a change in dielectric constant of say 10 per cent occurs because of the increased temperature of high-speed flight. The peak of efficient power transmission has now shifted to 9,500 mc./sec., and the transmission efficiency at this peak has dropped to 85 per cent. A change in dielectric constant causes the electrical thickness of the radome to change which may also produce angular bearing errors.

An additional effect of temperature on the radar system is the distortion of the antenna reflector which would reduce the obtainable resolution by increasing the beamwidth and generating side lobes. It is possible that a change in the angular bearing of the beam could also be caused by the reflector distortion.

Now again what can be done about these problems? The structural designers may contribute by designing antenna reflectors which are stable dimensionally with temperature. In cooperation with the radome electrical designer they can work toward the development of new, higher strength radome materials. This might be done by integrating metal into the radome itself in a fashion similar to concrete reinforcing. The materials people

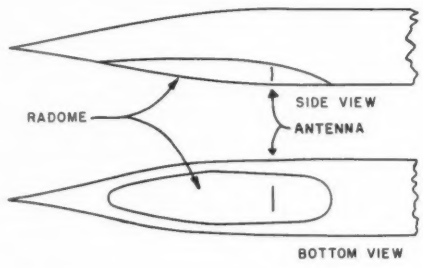

FIG. 3. Nose radome on modern high-speed bomber.

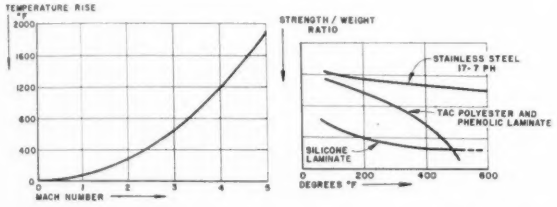

FIG. 4 (*left*). Increase in boundary-layer temperature with speed. FIG. 5 (*right*). Radome materials: strength/weight ratio vs. temperature.

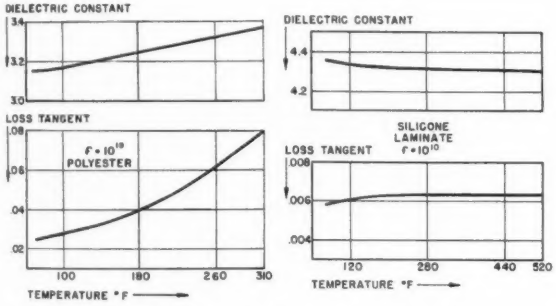

FIG. 6 (*left*), FIG. 7 (*right*). Dielectric constant and loss tangent vs. temperature.

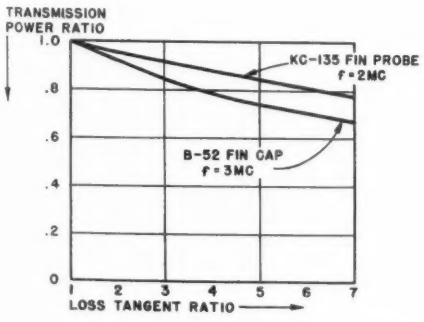

FIG. 8. Effect of increase in dielectric loss tangent.

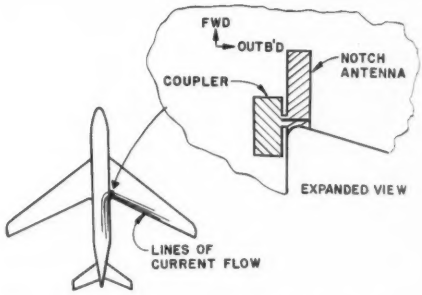

FIG. 9. Notch antenna at wing trailing edge.

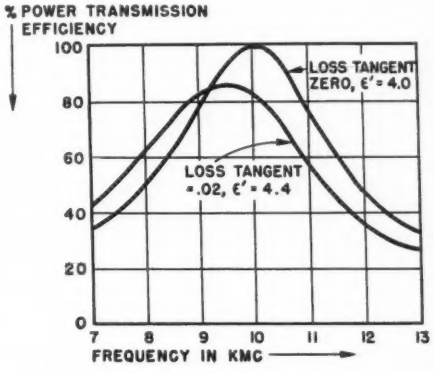

FIG. 10. Effect of electrical property change in radome material.

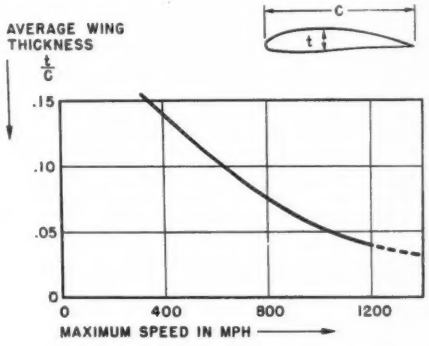

FIG. 11. Decreasing wing thickness with speed.

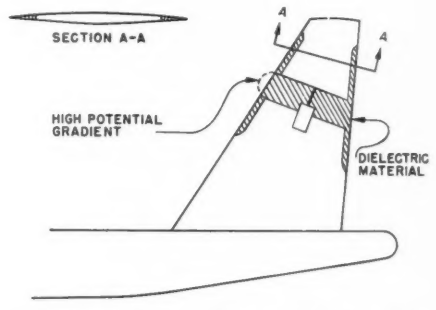

FIG. 12. Dielectric material around feed point.

can assist by improving both the structural and electrical properties of materials at elevated temperatures or by working with the electrical designer in the development of lightweight materials in which the dielectric properties may be artificially controlled. The antenna designer can attack these problems by development of antennas which do not need large dielectric radomes. For instance, arrays of small phased slots may provide equivalent radiation with much smaller dielectric radome units covering each slot. Electrical people could also devise means for detecting incipient physical failures in radome structures which could assure that a radome was in perfect condition before the initiation of a long flight.

The airplane shapes which are made necessary by higher speed flight cause problems for the antenna system designer. Characteristics of these shapes are the long pointed nose, a minimum diameter fuselage, and very thin airfoils often only an inch or two thick at the tips. The trend toward these shapes can be seen from Fig. 11 which shows the decreasing wing thickness with speed.

Lower strength dielectric materials at high temperature plus a decrease in airfoil thickness nearly prohibit the use of present-day dielectrics in an isolated tail cap antenna. Also, it is difficult to support a long probe antenna from a narrow fin structure without providing a faired bulge with its inherent drag penalty. The narrow fin does not provide sufficient mounting space for the antenna matching coupler, let alone extra space needed for its cooling provisions. Present couplers are roughly 7 in. in diameter which is at least double the mounting space dimension. The sharp leading edges and the thin cross section of the fin greatly increase the voltage breakdown and corona problem with the high radio frequency voltages used.

Development toward a miniaturized antenna coupler is a requirement for the electronic designer. The structural and antenna designers together may find means of replacing the metallic structure in the vicinity of the antenna feed point to increase the antenna to structure spacing (see Fig. 12), thereby reducing voltage gradients and breakdown problems. The antenna designer can find new means of exciting the aircraft structure as an antenna, such as the notch previously described.

The minimum diameter fuselage and long pointed nose make it difficult, and in some cases impossible, to install the increasingly large radar antennas required for the narrower beamwidth desired. This same shape characteristic requires excessive skin cutouts with related aircraft structural and radome problems (see Fig. 3). An electrical challenge is the transmission of energy through radomes at nearly grazing angles.

Solutions to these problems lie primarily in electronic and antenna development areas. Electronic system designers should seek techniques for obtaining narrower beams with given apertures by the application of electronics. The supergain antennas often suggested are known to have impractically narrow bandwidths.

Conclusion

To summarize, antenna system problems in high-speed aircraft will require the combined and cooperative efforts of structural, antenna, and radome designers for their solution. Each of the above engineering fraternities can contribute in significant measure to the solution of aircraft antenna problems often considered to be the sole headache of the antenna designer. It is recommended that in the development of any new weapons system or electronic subsystem that these engineers get together early in such a program.

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Air-Borne Computers . . . (Continued from page 78)

Outputs

Aircraft position in latitude and longitude in terms of
- Direction and distance to go
- Relation to schedule or flight plan
- Collision warning
- True air speed
- True ground speed
- Wind velocity and direction
- Rate of change of wind velocity and direction
- Remaining fuel
- Fuel at destination (hours and weight)
- Relation to PNR with and without fuel reserves

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ELECTRONICS IN AVIATION

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The Probability of Occurrence of Radar Echoes Over Areas of Arbitrary Size

A method for finding the amount of time that weather echoes detected by ground-based radars will spend over a smaller subarea of arbitrary size when statistical data on echo occurrence of a large region are known.

Introduction

Echoes from precipitation are quite frequently detected by most microwave radars. Indeed, radar has become an invaluable tool in short-range weather forecasting in that the trajectory of a detected storm may be plotted with great accuracy. With the advent of more radars specifically for radar-weather purposes, there is becoming available a large body of data on the statistical distribution of storm echoes at selected stations. It is the purpose of this paper to describe a method for finding the probability of occurrence of a radar echo over an area of arbitrary size when the radar-echo statistics of a large region are available. With this method one may find, for instance, the rainfall probability over a watershed for water conservation estimates or perhaps evaluate the results of a cloud-seeding experiment in an attempt at weather modification of a particular region.

Radar and Weather

Radars using different wavelengths, output powers, receiver characteristics, and antenna sizes differ also in their ability to detect precipitation. For example, a 1-cm. radar using a large dish looking directly overhead can detect clouds even without precipitation whereas the usual 10-cm. radar rarely, if ever, sees cloud. Attenuation by cloud and rain, however, is quite severe on the 1-cm. radar while the 10-cm. set is seldom affected by attenuation. An intermediate wavelength is optimum as far as the principal interests of the meteorologists are concerned. Atlas and others have shown that C-band (specifically 5.7 cm.) is perhaps best if one desires to detect precipitation and at the same time avoid the effects of attenuation. Most radars in use today in the microwave band are either 3-cm. or 10-cm. radars, and our experience with them has led to the bulk of our knowledge concerning the science of "radar weather."

Let us turn to the question of what types of precipitation the radar detects. Experienced radar observers know that they can track moderate and heavy summer showers quite accurately, and, indeed, short-term forecasting of showers by radar is highly dependable. On the other hand, widespread light precipitation, stemming from warm-front situations, is frequently undetected by radar. One can compute, given the radar characteristics, which rain and snow intensities will be detected by that radar set. Such computations clearly point out the fact that rain, in general, is much more readily detectable than snow. The dielectric constant of water is five times that of ice, and therefore echoes from rain will be much more intense than those from snow containing the same amount of water.

To find how well information obtained from a particular radar fits in with the above considerations, we will show the results of a study we made of records kept by the U.S. Weather Bureau Station at the Chicago Midway Airport on their AN/APS-15A 3-cm. radar. Radar observations were begun there in January, 1953; these were considered to be the longest set of such data in existence at the time this study was begun. This radar has a peak power of 15 kw., 1/2- and 1-microsec. pulse lengths, a 3° beamwidth, and can yield a B/S ratio of 0.5 at 15 miles on a 20-m.^{2} target.

The percentages of time that precipitation echoes were present anywhere on the radar scope were derived from the records; these are shown in Table 1. When averaged over the 3-year interval 1953–1955, inclusive, these data result in the graph shown in Fig. 1. The low values seen during the winter months result from the previously mentioned fact that snow has a lower

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* Senior Physicist.

Grateful acknowledgment is made to Ethel P. Fyler for her aid in reducing the data and in the computations which are a basic part of this paper and to Doris Rubenfeld for the illustrations. In addition, I am indebted to the U.S. Weather Bureau for making the radar and weather data available for this analysis.

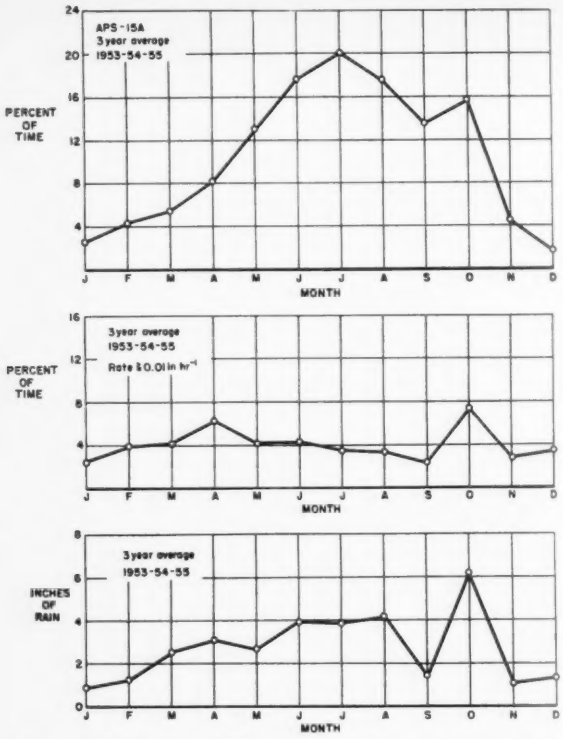

FIG. 1 (*Top*). Probability of precipitation echo on radar at Chicago. FIG. 2 (*Center*). Probability of rain at Chicago. FIG. 3 (*Bottom*). Total rainfall at Chicago.

reflectivity than rain and also that the winter rains, on the average, have lower liquid water content than summer rains. Clearly, the summertime peak stems from the more intense summer showers. It is possible that the secondary peak in October would not appear were the data averaged over a much longer time.

If we plot the percentage of time it rained at Chicago during the 3-year period discussed above, we find the curve shown in Fig. 2. Snow and drizzle were omitted from the computations.

Two facts are clear from a consideration of the curves shown in Figs. 1 and 2. (1) As one would expect, the curves are not alike. The radar detects precipitation falling anywhere over an area—say 8,000 sq. miles in extent—whereas rain at Chicago is measured essentially at a point. (2) The peaks occur at different times: It rains a greater number of hours in April whereas the maximum in the radar time-of-detection curve occurs in July.

If, on the other hand, we plot the curve of average rain intensity over the same period, we find the curve shown in Fig. 3. This curve has a minimum during the winter and a maximum in the summer; it is similar to an average rain intensity curve for most eastern or midwestern sections of the United States. The similarity between Fig. 1 and Fig. 3 stems from the fact, as one would anticipate, that the radar detects the more intense summer rains; in addition, these summer showers extend to greater altitudes and hence are detected at larger distances.

TABLE 1

Percentage of Time the AN/APS-15A Radar Detects Precipitation at Chicago

Month	1953	1954	1955
January	1.1	2.7	3.9
February	1.2	7.4	4.7
March	5.2	6.5	4.4
April	2.1	..	14.4
May	10.4	..	15.8
June	15.8	24.3	15.2
July	24.7	10.7	25.2
August	17.3	23.3	12.5
September	13.0	17.0	8.3
October	6.4	19.6	21.5
November	2.1	6.5	5.2
December	2.4	2.4	0.6

Let us return to a consideration of Figs. 1 and 2. A large discrepancy exists during the summer: The radar detects precipitation at least somewhere in its detectable range as much as 20 per cent of the time in July whereas it only rains about 4 per cent of the time at a point. The random nature of summer showers permits us to attack the problem statistically. If one were given the statistics of the radar echoes over an area, how could one find the probability of the existence of an echo over some smaller area of arbitrary size and, indeed, even over a single point within the area? It should be stressed at this point that we will only ask for the probability of a radar echo existing over an area and not the probability of rain falling on that area. The relationship should be close, but it is not one-to-one since radars can detect rain even though it does not reach the ground. Widespread, uniform rains, the type associated with warm-front situations, will not be considered in this treatment since they are not amenable to a statistical attack.

THEORY

We shall begin by assuming that rain storms are cellular in structure with individual cells shaped in the form of circular cylinders; they travel with uniform speed v across the area of detectibility of the radar. We shall also assume that cells move with a speed independent of their size and that the likelihood of occurrence is equal in all portions of the detectible area. From the statistics obtained from a radar at a particular location, one may find the differential probability distribution $p_1(h)$ of the echo sizes, where h is the diameter of the radar echo. Likewise, one may also obtain the statistical distribution of the echo speeds $p_2(v)$ by

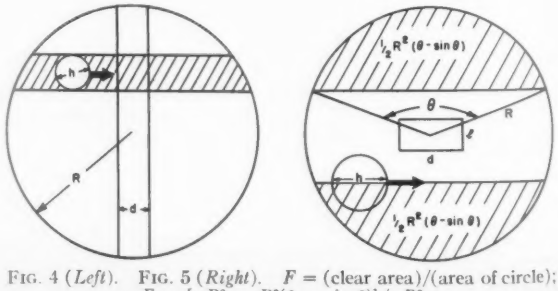

FIG. 4 (*Left*). FIG. 5 (*Right*). F = (clear area)/(area of circle); $F = [\pi R^2 - R^2(\theta - \sin\theta)]/\pi R^2$.

measurements of radar photographs of many storms. In the absence of direct velocity measurements one may obtain $p_2(v)$ from the results of pibal measurements, utilizing the now-accepted fact that storms move with winds at the middle altitudes, say 5,000 ft. The echo size and wind probability distributions will, of course, vary with the seasons.

With $p_1(h)$ and $p_2(v)$ available, we are now in a position to find the average time an echo spends crossing a strip of width d within the area of detectibility of the radar (see Fig. 4). For the average time spent crossing d we may write

$$\bar{t} = \frac{\int_0^\infty \int_0^\infty t(d, v, h)p_1(h)p_2(v)dh\,dv}{\int_0^\infty \int_0^\infty p_1(h)p_2(v)dh\,dv} \qquad (1)$$

where t is the time it takes an individual echo of diameter h to cross d. Eq. (1) considers a strip on the ground whose short dimension is d and whose long dimension is $2R$ when R is the mean radius of detectibility. (A radar with a given peak power, beamwidth, and receiver sensitivity can detect a given rain intensity at some maximum range R, here defined as the radius of detectibility, provided that no attenuation occurs. Since R depends on rainfall rate and storm height, it is clearly a variable, so we speak here only of its mean value.) If we now restrict the area even further to a rectangle of width d and height l, we may rewrite Eq. (1) as

$$\bar{t} = \frac{\int_0^\infty \int_0^\infty F(l, h, R)t(h, d, v)p_1(h)p_2(v)dh\,dv}{\int_0^\infty \int_0^\infty p_1(h)p_2(v)dh\,dv} \qquad (2)$$

where $0 \leq F \leq 1$.

Let us discuss the parameter F. The area of a segment of a circle (see Fig. 5) is given by

$$(1/2)R^2(\theta - \sin\theta)$$

Note that all echoes whose centers pass within $\pm[(l + d)/2]$ of the center of the circle touch at least some part of the area of interest, hence we ask for the difference between the area of the circle and the area of the two segments; this is indicated as the clear area in Fig. 5 and is given by

$$\pi R^2 - R^2(\theta - \sin\theta)$$

The parameter F is the ratio of the clear area shown in Fig. 5 to the area of the circle of detectibility—that is,

$$F = (1/\pi R^2)[\pi R^2 - R^2(\theta - \sin\theta)]$$

or

$$F = 1 - (1/\pi)(\theta - \sin\theta) \qquad (3)$$

A plot of F against θ is given in Fig. 6. The value of θ may be obtained by

$$\theta = 2 \arccos[(h + l)/2R] \qquad (4)$$

When Eqs. (3) and (4) are inserted into Eq. (2), it is clear that integration becomes difficult. We may

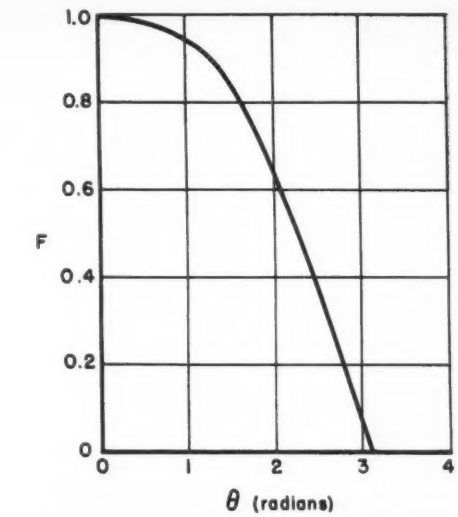

FIG. 6. Parameter for radar-echo width and l dimension of area.

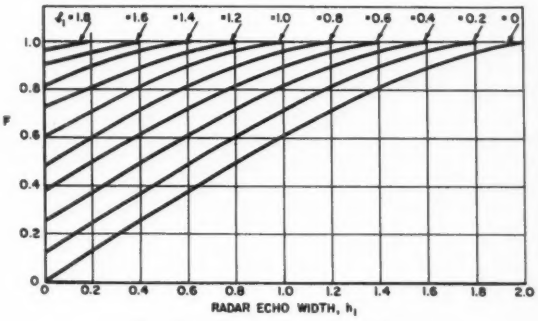

FIG. 7. F vs. radar-echo width.

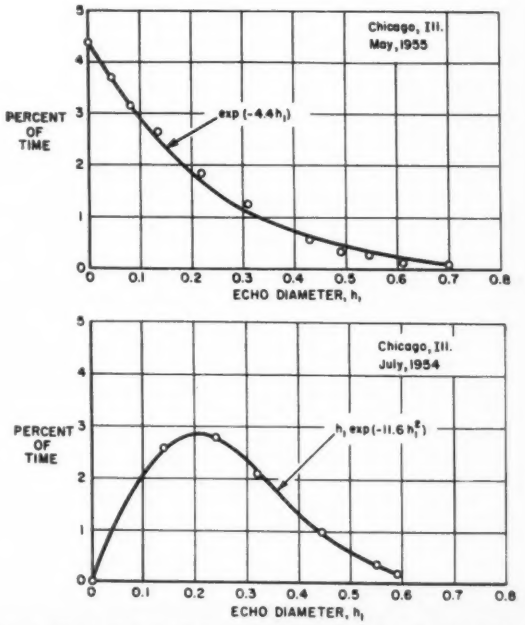

FIG. 8 (*Top*), FIG. 9 (*Bottom*). Probability distribution of echo sizes.

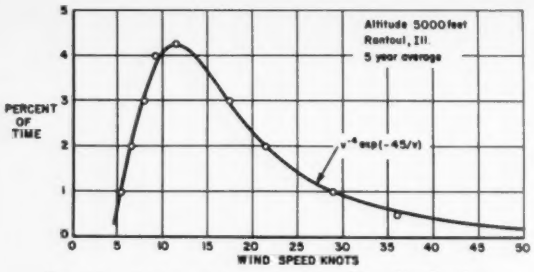

FIG. 10. Radar-echo speed probability distribution.

simplify this integration by letting

$$F(l, h, R) = F(l_1, h_1)$$

where $h_1 = h/R$ and $l_1 = l/R$—that is, we shall now discuss echo sizes and the size of areas on the ground as ratios of these sizes to the mean range of detectibility. We may obtain θ, then F, in terms of h_1 for various values of l_1. The F may now be plotted against h_1 for selected values of l_1; these curves are shown in Fig. 7. These curves can be expressed approximately as

$$\left.\begin{aligned} F &= mh_1 + b \qquad h_1 \leq h_1' \\ F &= 1 \qquad\qquad h_1 > h_1' \end{aligned}\right\} \tag{5}$$

with an accuracy of about 4 per cent. The values m, b, and h_1' for various l_1 are given in Table 2. In the form given by Eq. (5), the F parameter becomes more easily manageable when substituted into Eq. (2).

In Eq. (2) the time for an echo to move across a distance d was given by t. If d_1 is defined as $d_1 = d/R$, we may write

$$t = (h + d)/v = [(h_1 + d_1)/v]\, R \tag{6}$$

Let us now turn our attention to the probability distributions used in Eq. (2). Here we draw on the statistical data obtained from the actual radar measurements.

The data given by the Weather Bureau are in the form of half-hourly reports on areas of precipitation; their sizes and their positions relative to the station are recorded. From these records we obtained a series of graphs of the differential probability distributions of areas for the summer months during the 3-year observation period. From these graphs we formulated analytical descriptions of the two forms of the differential probability distribution of radar echoes. These were

$$p_1(h) = e^{-kh}\, dh \tag{7}$$

$$p_1(h) = he^{-kh^2}\, dh \tag{8}$$

TABLE 2

l_1	m	b	h_1'
0.0	0.57	0.00	1.76
0.4	0.53	0.25	1.42
0.8	0.48	0.48	1.07
1.2	0.39	0.72	0.72
1.6	0.28	0.90	0.36
2.0	0.00	1.00	0.00

The closeness of fit of Eq. (7) to the data of May, 1955, is shown in Fig. 8; the probability distribution is shown by the circled points, and the analytical form is indicated by the solid line. The form given by Eq. (8) is illustrated in Fig. 9 along with the data for July, 1954. In these curves, the echo sizes are indicated along the abscissa in terms of their equivalent diameters.

For the present analysis the wind probability function was derived from readily available pibal data taken at Rantoul, Ill. The data were averaged over a 5-year period for the three seasons, spring, summer, and fall. A relationship between wind and radar echo speed has been shown previously by Byers* and Braham to be

$$U_{wind} = 1.9 + 0.65U_{radar} + 0.02U_{radar}^2 \tag{9}$$

If we take the 5-year average mentioned above and modify it by Eq. (9), we find a probability function which follows closely:

$$p_2(v) = v^{-4} \exp(-45/v)\, dv \tag{10}$$

The data (circled points) and the analytical form (solid line) are shown in Fig. 10.

We are now in a position to integrate Eq. (2). The average value of the time it takes the echoes to cross an area of width d_1 and length determined by h_1' (see Table 2) is given by

* Byers, H. R., *Thunderstorm Electricity;* University of Chicago Press, Chicago, 1953.

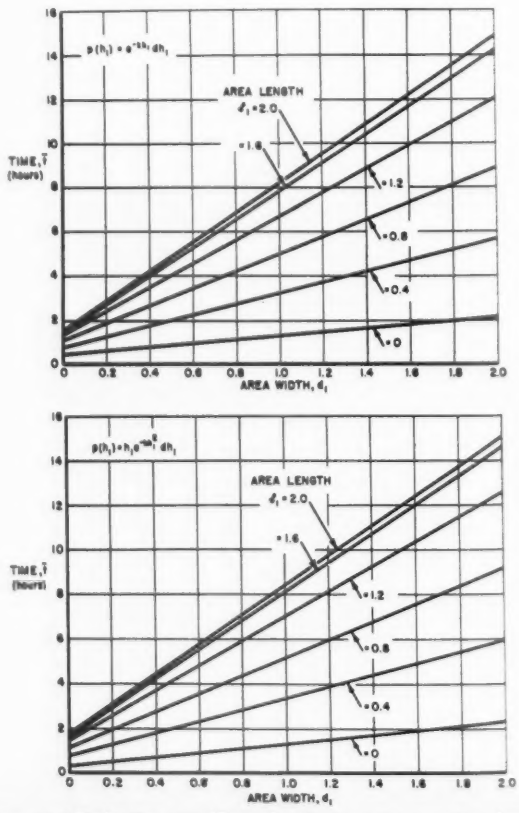

FIG. 11 (*Top*), FIG. 12 (*Bottom*). Radar-echo crossing times.

$$\bar{t} = \frac{R\int_0^{h_1'}\int_0^{\infty}(mh_1+b)(h_1+d_1)\exp(-k_1h_1)v^{-5}\exp(-45/v)dh_1\,dv}{\int_0^{2}\int_0^{\infty}\exp(-k_1h_1)v^{-4}\exp(-45/v)dh_1\,dv} + \frac{R\int_{h_1'}^{2}\int_0^{\infty}(h_1+d_1)\exp(-k_1h_1)v^{-5}\exp(-45/v)dh_1\,dv}{\int_0^{2}\int_0^{\infty}\exp(-k_1h_1)v^{-4}\exp(-45/v)dh_1\,dv} \quad (11)$$

if we use Eq. (7) for the radar-echo size distribution. The variables h_1 and v are separable, and the integration may be carried out readily. The terms involving the wind speed can be put into the form of a gamma function and integrated. Thus Eq. (11) is simplified to

$$\bar{t} = \frac{(300/45)\int_0^{h_1'}[mh_1^2+(md_1+b)h_1+bd_1]\exp(-k_1h_1)dh_1}{\int_0^{2}\exp(-k_1h_1)dh_1} + \frac{(300/45)\int_{h_1'}^{2}(h_1+d_1)\exp(-k_1h_1)dh_1}{\int_0^{2}\exp(-k_1h_1)dh_1} \quad (12)$$

The integrations remaining in Eq. (12) performed term by term result in a set of values of crossing times dependent upon the size of the area being considered. Fig. 11 gives the set of average crossing times $\bar{t}$ for various values of d_1 and l_1 as computed from Eq. (12). Another set of $\bar{t}$ values may be derived for the error function form of the echo size distribution given in Eq. (8). These are presented in Fig. 12. It is interesting to note that, although the differential probability distributions have dissimilar shapes as given by Eqs. (7) and (8), the resulting crossing times are remarkably alike—they differ by less than 20 per cent. One should note also that some asymmetry exists along the d_1 and l_1 directions—i.e., parallel and normal to the mean direction of travel of the storms.

The total time per month, let us say, that echoes are present over an area of arbitrary size is, then, equal to the average time for each storm multiplied by N, the number of individual storms per month; this product should then be multiplied by P, the probability of echo occurrence—i.e., the number of hours during which an echo appears anywhere on the scope divided by the total number of hours in the month. Thus, the total time may be written

$$T = P\bar{t}(N/Q) \quad (13)$$

The factor Q is introduced here to take into account the fact that some cells dissipate before crossing the entire radar detection field. (In the analysis, $\bar{t}$ was derived assuming all echoes crossed the field without dissipation.) Secondly, Q involves the likelihood of existence of two or more echoes simultaneously. It is clear that, for measurements at a point, only one echo is possible at one time. However, as the size of the area of interest increases, so does the probability that two or more echoes exist in the field at one time. This has the effect of decreasing the effective N in the evaluation of T. The values of N and Q may be obtained directly from the radar scope where continuous photographs are available.

Continuous photographs were not taken on the APS-15A for the period under discussion; however, it was possible to obtain the limits of N/Q by solving Eq. (13) for N/Q, then substituting measured values of T and P from the data and the theoretical values of $\bar{t}$ at $d_1 = l_1 = 0$ and $d_1 = l_1 = 2$. We find by this method that

$$1.0 \leqslant Q(d_1,l_1) \leqslant 7.1$$

This is equivalent to a scale transformation in $\bar{t}$. Assuming no relative changes in $\bar{t}(d_1, l_1)$, we may obtain a set of values for $Q(d_1, l_1)$. These are given in Fig. 13.

We now are in a position to find what we set out to obtain—namely, the number of hours we would expect radar echoes to exist over areas whose size is given by d_1 and l_1. If the value of P [Eq. (13)] is determined for a particular region and a particular month and it is found that the probability distributions as given here hold for that region, one may compute T from the values given in Figs. 11 or 12 and 13.

Conclusion

The method presented in this paper is a statistical approach to the problem of finding the probability of showery-type precipitation echo existing over preselected smaller areas, given the statistics of echo occurrence within the range of detectibility of a radar

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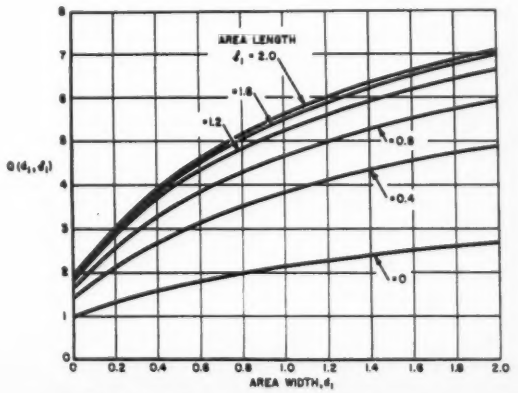

FIG. 13. Parameter for cell dissipation.

ELECTRONICS IN AVIATION

Col. S. A. Mundell,* USAF
Air Research and Development Command

Air Force Air Traffic Control

Opinions on the control of air traffic and airspace from an Air Force point of view.

FROM A MILITARY point of view, the control of air traffic divides itself into two phases—peacetime operation and operation during time of war or national emergency. These two phases are so interrelated that at times it is impossible to differentiate between them. With the foregoing in mind, my first opinion is that *there can be but one system for the control of air traffic or airspace during either phase.*

Training requirements dictate that the wartime system operate in the same manner as does the one which is used in time of peace. If a war is declared, time will not permit us to install a separate system nor to train our pilots and maintenance personnel to use or operate it. During World War II, four-course ranges, homing beacons, and control towers were installed on airways and at air bases all over the world in order to provide navigation and landing aids for our aircraft. As a matter of fact, in helping prepare for the invasion of North Africa, I sent an aircraft and an engineer back here from England to pick up a four-course range and fly it to Oran, Algeria. It was to provide a navigation facility to be used by the aircraft which were to participate in the invasion. Even with these special arrangements, it was not in place and operating until 3 days *after* the landing took place. The only alternative to this is the installation of a separate military system, complete with its own control authority upon which to conduct training, but I do not believe this to be in the national interest. It would not only be hazardous but economically impractical. The old GCA-ILS controversy and the TACAN-VOR discussions are examples of this type of thinking. However, they represent minor problems compared to the one which may erupt between the SAGE-non-SAGE advocates.

If there can be but one system of air traffic control, my second opinion is that *there can be but one organization for the control of aircraft and airspace wherever military aircraft fly.* The reasons supporting this opinion are involved in operation, policy and its legal aspects, economic considerations, and personal experience.

From a military point of view, airspace—and, in this instance, I use the term loosely—can be controlled by three separate United States agencies: the Civil Aeronautics Administration (CAA), the Airways and Air Communications Service (AACS) which is a part of the Military Air Transport Service (MATS), and the Air Defense Command. Most people are aware, I am sure, of the functions and responsibilities of the CAA and the Air Defense Command, but few have heard of the AACS although it is one of the oldest of the Air Force Commands. It was formed in 1938 at the direction of Gen. Hap Arnold and charged with the control of the Air Corps Aircraft and with transmitting the messages relative to that control. From a modest beginning of 300 personnel, it grew during World War II to a complement of some 2,500 officers and 200,000 men located on every air base throughout the world at which military aircraft landed. It has, incidentally, the dubious distinction of having preceded General MacArthur into Tokyo in order that his aircraft could be provided navigation assistance and landing instructions upon its arrival. With the cessation of hostilities and the formation of a separate Air Force, the AACS was handed the additional duty of providing administrative and operational communications service for the Air Force and its major Commands. Presently, the organization consists of some 1,500 officers and 25,000 airmen located on military air bases in all theaters of operation throughout the world. During my recent tour as Commander of the Continental Wing of AACS, I had assigned to me 600 officers and 12,000 airmen and civilians who were dispersed at 142 separate air bases and locations throughout the United States. It should be noted that they constituted but 40 per cent of the worldwide commitment. If the Korean experience can be taken as an indication, it must be expected that, in the event of another war, the AACS will again be expanded to at least its World War II size and activity. This being the

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* Chief, Air Traffic Control and Navigation Division, Directorate of Systems Management, Detachment #1, Wright-Patterson AFB, Ohio.

case, then its peacetime activity must cater to this foreseen expansion.

With this in mind, my third opinion is that *the agency responsible for the control of air traffic and the airspace in which to control it must be a joint one and must be made up of at least the CAA and AACS.*

Let us examine my reasons for this opinion.

While the CAA is responsible for the control of air traffic within the continental United States and its territories, I have pointed out that the AACS in fact controls a great deal of the military traffic in these areas. This is done by agreement with and in conjunction with the CAA. In general, these agreements govern the control of IFR traffic; however, the Air Force has long had a requirement for the control of VFR traffic. This control was, until recently, exercised by the Air Force Flight Service. This organization and its functions are presently being absorbed by the AACS. With the increased speeds and operating ceilings of some of the newer aircraft, every Air Force flight will be under IFR control in the near future. The increased load on the traffic control agencies will require additional operating personnel.

Logically one may ask, "If you believe that only one agency should control air traffic and the CAA has that statutory responsibility, why is the control not turned over to it in total?" The answer is that (1) it is not large enough, and (2) the overseas and wartime commitments are such as to require continued *military* participation. By saying that the CAA is not large enough I do not mean to be critical but simply to point out that, in the United States alone, its manpower would have to be at least doubled, and that, if the territorial operation is also considered, its number would probably have to be tripled. The problem of procuring and training the necessary personnel would be stupendous.

I have made the point that 60 per cent of the AACS commitment is overseas and that its facilities are located at air bases and along the airways in every theater in the world. This naturally means that most of the locations are in foreign countries—England, France, and Japan, for example. It is relatively simple to negotiate a military agreement which allows the operation of military radio equipment within these countries, but, in discussing the problems which would be involved in obtaining similar rights for a civil Government agency, I have been informed that they would be manifold, if not impossible.

Supposing, however, that this could be done; then the CAA would be faced with an even greater expansion. What would happen if a war were declared?

Harking back to Korea again, if memory serves me correctly, the CAA had personnel in Seoul at the outbreak of hostilities, and they were withdrawn and replaced by military personnel almost immediately. During my Alaskan tour, the Regional Administrator and I spent a great deal of time trying to evolve a plan by which the CAA civilian personnel would be replaced by military in case a "shooting war" started. (And believe me, the threat in Alaska is not too distant.) Our main problem was in determining how long the civil operators could be made to stay on their jobs once war was declared. We were never able to reach any firm conclusion, but I did have in my files complete information on each installation so that I might request the personnel necessary to operate them. We both believed that this replacement would be necessary. How, then, can this expected expansion be manned unless it is done by the military service?

Having proved, at least to my own satisfaction, that overseas operation must be done primarily by the military, it then follows that some of the operation within the United States must also be done by the military, otherwise there will be no place in which to train the overseas replacements.

Now my fourth and final opinion is that *the joint air traffic control agency must be integrated with the Air Defense Command during time of peace in order to ensure operational continuity in time of war.*

Air Defense Command is charged, by the Key West agreements, with protecting the United States from air assault and, in time of war, with controlling the air traffic within the United States. Defense against an air assault must be based upon knowing what aircraft are in an area—which are friendly and which are hostile. This is a continuing requirement and exists at all times during which there is even the remotest possibility that an enemy has the capability of launching such an assault. The main source of information as to the location and identity of friendly aircraft is the traffic control agency. This information must be available to the Air Defense Command on a continuing basis. I believe that this responsibility is of such magnitude that it requires the continued operation by one agency and that it cannot be assumed in the event of an attack and relinquished when the attack is over. The assumption of traffic control responsibility during an attack would so overload the Air Defense facilities as to preclude the performance of their primary mission—defense against the attack. The two functions, however, must be so integrated that each agency performs its portion of the task in full cooperation with the other during time of peace as well as during an attack. For this reason, I feel that all information sources available to one must be *usable* by the other.

Radar is one of the basic ingredients of both systems. Economic considerations dictate that, wherever possible, joint usage be made of presently installed equipment and that future installations be sited to the mutual benefit of both. Operating positions and computing and communications equipment may, of necessity, have to be separate.

I might point out, in passing, that these same requirements pertain to every potential combat theater throughout the world while the Air Defense Command is limited to the continental United States and Canada.

In summary, I believe that:

(1) There can be but one agency charged with the control of airspace and air traffic.

(*Continued on page 113*)

ELECTRONICS IN AVIATION

Why the CAA must currently allocate "the diminishing airspace" on a joint use basis.

Airspace Use for Air Traffic Control and Air Defense

D. D. Thomas*
Civil Aeronautics Administration

OUR SUBJECT concerns a vital and unique national asset. Current demands on airspace are of such proportion that a popular cry is being heard in the aviation industry—what to do about "the diminishing airspace." Who are the users of airspace? How is it currently allocated? What are some of the problem areas, trends, and future outlook? These are questions I intend to amplify and perhaps, with your indulgence, arrive at a clear understanding of the problem.

With regard to the users of airspace, the Civil Aeronautics Administration by virtue of its responsibility to control air traffic has, under its jurisdiction, by far the largest portion of allocated airspace. These allocations are reflected in the nature of federal airways, control area extensions, and control zones. The military are the second largest users of airspace by virtue of their responsibility for training air and ground personnel and for permitting the conduct of other national defense activities. The airspace set aside for these functions is indicated as restricted areas, warning areas, controlled firing areas, prohibited areas, and caution areas. In addition, we have been recently faced with a demand on airspace by the telecasting and broadcasting industry. Their requirements are reflected in the form of tall TV transmitting towers which have been requested up to heights of 2,000 ft. above ground. Industry seeks further demands on airspace in the nature of free-floating high-altitude balloons, which are employed for the purpose of upper wind studies and cosmic ray and scientific research. These experiments are often conducted jointly with the military.

It is conceivable that these demands for airspace have a tendency to overlap with the culminating result that there exists competition for the same airspace. Therefore, it is essential that we have a clearing house, so to speak, where these demands are made known in advance to a qualified representative group whose responsibility calls for the careful study and "planned allocation of airspace." Some of the necessities and benefits derived from such planning are as follows:

(1) Safe integration of military and civil operations.
(2) Elimination of duplication of navigation aids.
(3) Provision of planning information for optimum location of new airports and bases.
(4) Location and adjustment in height of tall TV towers to minimize hazardous effect on air navigation.
(5) Exchange of operational information on aids in planning civil airway structure by the CAA.
(6) Provision of media at regional and Washington levels for civil, military, and private pilot organizations to present their views on operational problems.
(7) Provision of means to ensure maximum utilization of allocated airspace.

It is the function of the Airspace Panel of the Air Coordinating Committee to examine airspace proposals along the lines indicated above. Such a group exists at each of the CAA regional offices and is comprised of representatives of the Department of Commerce (CAA), Civil Aeronautics Board, Army, Navy, Air Force, and Federal Communications Commission. Each of these members is entitled to a vote. However, the Department of Commerce member in his deliberations must heed the requirements and philosophies of civil aviation associate members such as Air Transport Association, Aircraft Owners and Pilots Association, Airport Operators Council, National Business Aircraft Association, National Association of State Aviation Officials, and other interested civil groups.

To illustrate the procedure concerning a request for airspace, let us take a sample problem: A local military commanding officer of an air base is given a mission to train a number of aircraft bomber crews. As a matter of necessity, he seeks an area within which to perform vital phases of this mission. He makes his requirement known to the respective Regional Air Force Member of the Airspace Subcommittee, who then places this problem before the Subcommittee for consideration. At this working level, the proposed

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* Director, Office of Air Traffic Control.

area is examined with relation to existing activities of other agencies. During this course of examination, it may be necessary to make certain adjustments, or perhaps a different location is recommended where the activity could be carried out safely without interference with existing activities. A recommendation is made, voted upon, and forwarded to the Washington Airspace Panel which is comprised of similar representation of a higher organizational level. This case is again reviewed primarily from a standpoint of policy and future planning, and again a vote is taken on a specific recommendation. If the voting is unanimous, the matter is then processed for formal designation, notices to the public, and charting. If voting is split, the matter is then submitted to the Technical Division of the Air Coordinating Committee which comprises the next higher echelon in the ACC structure. It is conceivable that cases of an extremely controversial nature could reach the top ACC group and perhaps may require final resolution by the President. I am glad to report that, as of this date, we have had only comparatively few cases which necessitated Technical Division attention and none beyond that point.

This system, as evidenced by its past record, appears to have been operating in a satisfactory manner. However, by virtue of the diminishing airspace, we are currently faced with some problem areas. Figs. 1–5 depict the rapid increase in the allocation of airspace.

The first four figures represent a chronological growth of the CAA low-frequency - VOR airway structure, together with designated control area extensions and control zones.

Fig. 1 illustrates CAA control area designated as of 1941, during which time we operated a low-frequency airway system with airways 20 miles in width.

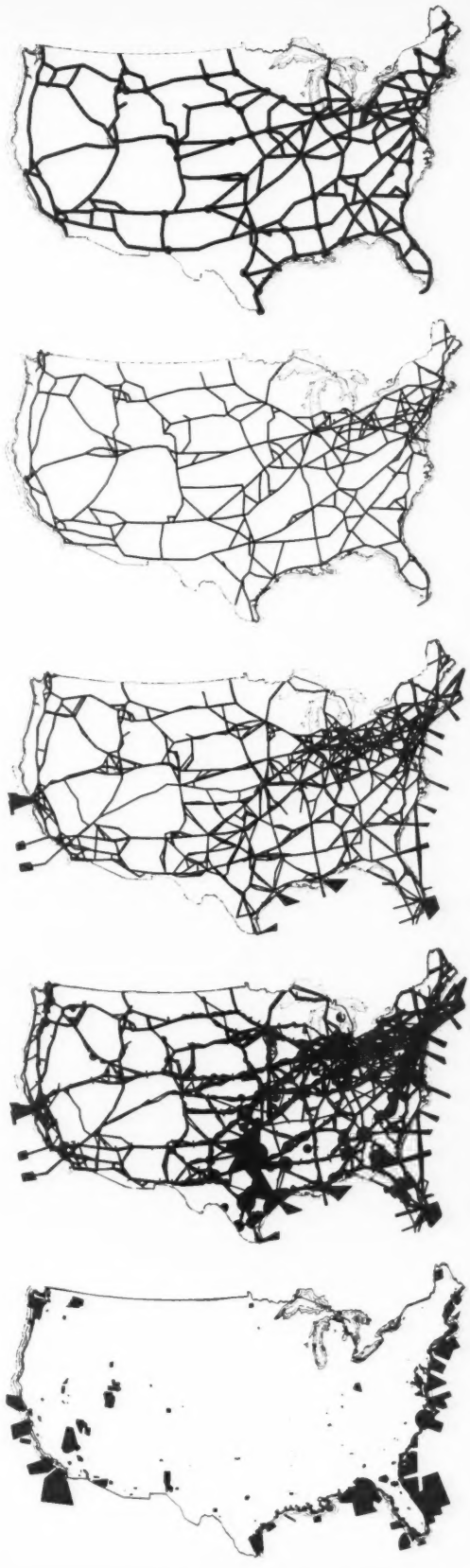
Fig. 2 illustrates similar control area as of 1947 with airways 10 miles in width. It may be noted at this point that the reduction in the width of airways was made possible because of refinements in navigation. (Date of conversion from 20 to 10 miles: July, 1943.)

Fig. 3 illustrates CAA control area as of December, 1952, which covers both low-frequency and VOR airways. As a matter of historical interest, the VOR airway system was inaugurated in October, 1950. You will note at this juncture that there was a rapid increase in allocation of airspace.

Fig. 4 illustrates CAA control areas as of 1955 as reflected by both the low-frequency and VOR airways. You will note by the shaded area that there has been a rapid increase in the number of airways and also in the size of circular control area extensions. It is interesting to observe that since the advent of jet penetration procedures there has been an attendant growth in the size of these control area extensions.

Fig. 5 illustrates a composite picture of the military warning and restricted areas as of December, 1955, some of which are being jointly used by the Service branches.

It is obvious from the illustrations that the requirements for the use of airspace are rapidly increasing to



FIGS. 1–5. (*Top to bottom.*)

a point where we are beginning to feel the "pinch." With this natural growth or squeeze, there is an attendant number of problems which we currently face and which appear to be generated more rapidly as time goes on.

The problem areas are brought about by the following conflicting interests:

(1) Neither civil nor military users desire to accept delays due to the other's activity.

(2) Civil users are unwilling to rely on military-operated radar as a primary means of monitoring civil aircraft movement in bombing or firing areas.

(3) Military agencies object to the establishment of civil airways or control areas through geographical areas with concentrated pilot training activity.

(4) Establishment of military air bases and civil airports in close proximity often create severe traffic problems to both military and civil alike. Long-range plans which relate to real estate acquisition are often not correlated with the airspace problem soon enough.

(5) Civil users do not desire to accept by-pass airways around heavy military concentrations of air traffic.

(6) Unfeasibility of "qualified" or "part-time" control areas with air route traffic control centers responsible for not only traffic separation but relay of other airspace activity to pilots.

(7) Lack of radio aids for navigation to remedy navigation problems introduced by increased military operations in certain areas.

(8) The concentration of the military activity in the south and southwest good weather area and the Navy activity along the coasts have accentuated the overall problem.

(9) Military testing of new weapons such as guided missiles require thousands of cubic miles of airspace.

(10) The vertical definition of a control area is fixed by CAR 60. Large areas up to 60 miles in radius are currently designated for jet penetrations and extend down to 700 ft. above ground.

(11) Installation of various types of NAV aid systems such as Low Frequency, VOR, TACAN, and VORTAC which tend to cut inroads on airspace and also complicate the air traffic control problem. This problem will be diminished with the transition to VORTAC.

(12) Joint use of airspace by civil and military operations not always possible because of lack of communications and control facilities to notify users when safe penetration can be made.

At this point, I would like to summarize briefly and arrive at some general conclusions:

(1) There exists a fundamental conflict for the use of the same portions of the airspace arising, on the one hand, from national defense requirements and, on the other, from the development of the aviation industry (including general aviation) as an integral part of the national economy. This situation is becoming more critical as aircraft speeds and mileage flown increase and with the introduction of new long-range weapons.

(2) The general problem of "the diminishing airspace" is of such magnitude and complexity that the solution of the individual conflictions previously outlined can be effectively reached only through an overall study at a policy level.

(3) Policy level decisions in these areas will be necessary in order that individual cases can then be more effectively handled at operational levels. Some examples are:

(a) The impact on both civil and military operations arising from the nonavailability of airspace to meet air traffic needs and to satisfy current and future military requirements for restricted (and warning) areas in which to test and train in the use of new types of weapons and aircraft.

(b) The need for development of a traffic control system capable of integrating jet let-down approach and departure procedures, with both terminal and en route air traffic of all types.

(4) The need for the development of an airway system structure better adapted to present and foreseeable future requirements, necessitating extended use of radar, use of higher altitudes, communications, and control equipment.

Insofar as the Department of Commerce is concerned, it is recognized that the extent of control areas designated within the United States exceeds by a considerable figure the area covered by civil airways. This is because control area extensions of varying dimensions have been established to encompass the area required for (a) conventional instrument approaches to airports, (b) jet penetrations, and (c) radar vectoring in terminal areas and normal transition procedures in terminal areas.

The amount of control area would be reduced substantially as low/medium frequency facilities which implement associated airways, and do not overlap VOR airways, are decommissioned. As previously pointed out, however, there is a pressing requirement to provide increased air traffic control service, which will lead to the designation of all airspace as control area at high levels, excepting those Restricted, Prohibited, and Warning Areas, which may extend above 24,000 ft. msl.

Expansion of either the short-range navigation system to give increased coverage at lower altitudes, in addition to new airway implementation, will encourage the designation of additional control areas at low levels. The flexibility of an omnisystem will suggest more control area to accommodate multiple tracks; however, with the greater use of the distance-measuring equipment, it is expected that more efficient use of available airspace will result.

In my discussion, I have touched on the general trends and some of the thinking within the CAA. We are continually striving to plan sufficiently in advance; however, it appears we have not moved rapidly enough to keep pace with the continual demands of the aviation industry. As a general illustration, we recently submitted to Congress and have had approved a 5-year plan for the installation of NAV aids and the

control of traffic, which now must be compressed into a 3-year program. In spite of our many years of experience in this field, we do not presume to have all the answers. We are always receptive to any contributing ideas that may be generated by organizations such as the Institute of the Aeronautical Sciences.

In conclusion, I would like to convey one thought with regard to the current airspace situation. We have reached a point of saturation to the degree that we can no longer allocate airspace for the exclusive use of any one activity, and we must keep in mind the necessity for the concurrent joint use of airspace.

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Radar Echoes Over Areas of Arbitrary Size *(Continued from page 107)*

set. The illustrative examples given here were taken from a 3-year set of observations on 3.2-cm. radar. The observations were made at half-hourly intervals when precipitation was occurring. This is clearly a limitation on the accuracy of the data. Experiments of a similar nature are being planned elsewhere which should shed more light on this subject. In these experiments, continuous photographs are to be taken of the radar scope during periods of precipitation. With these data, measurements of the life span of individual cells will be possible. For purely meteorological purposes it would be more enlightening if these studies were carried out on a C-band radar. This would lessen the deleterious effects of attenuation. It is hoped that the method presented here will be useful in analyzing the data from such experiments.

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Air Force Air Traffic Control *(Continued from page 109)*

(2) This must be a joint agency since the problems of military operation dictate a military component within the United States to support overseas manning and training during peacetime.

(3) The continental component could supply the initial requirements of the expected wartime expansion.

(4) The Air Defense Command cannot exercise its directive of protecting the United States from an air assault unless it is fully coordinated with the traffic control agency during time of peace.

(5) Congress must take cognizance of this problem and rectify the laws which it has passed in order to make such a joint operation possible.

I have no approved solution as to the organizational structure necessary to staff such a joint agency. However, from previous experience I know that it must be given the authority to direct joint participation, adjudicate differences of opinion, and furnish the funds with which to finance, install, and conduct the entire operation.

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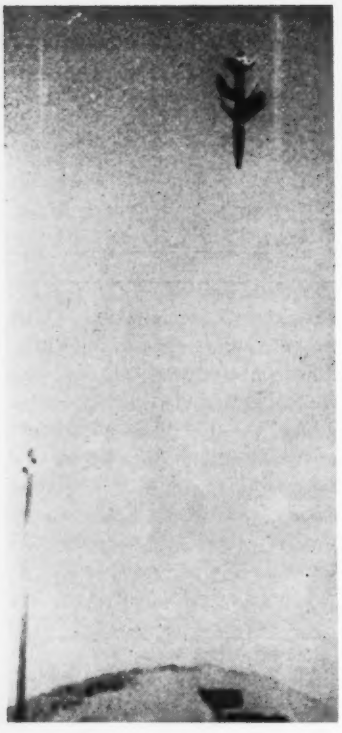


ELECTRONICS IN AVIATION

A Report on Missile Development

A digest of addresses that comprised the Guided Missiles Session of the IAS 25th Annual Meeting, New York, January, 28–31, 1957.

The Guided Missile Session attracted an audience of more than 500, taxing the capacity of the North Ballroom of the Sheraton-Astor Hotel. Many stood—some for 3½ hours—to hear three of the United States' foremost military figures in the missiles field.

The length of the Air Force, Army, and Navy presentations precludes their publication in complete form. Yet, the REVIEW *has attempted in this condensation to record the material of most interest to its readers. The addresses are recorded here in alphabetical order.*

Rear Adm. J. E. Clark, USN

Director, Guided Missiles Division, Office of DCNO (Air)

While the United States has achieved measurably great success in missile development (so great that "the Sixth Fleet is prepared to fight a war, with missiles"), much more work is necessary to improve reliability, and means must be taken to halt ever-spiraling unit costs, Admiral Clark declared. "Unless we do something about it and do it quickly," he warned, "all the glowing success" in getting missiles flying "will be meaningless."

Admiral Clark said he felt certain that "as much of the blame for the high price of our missiles rests with the military as with industry. In some cases we insist on out-dated specifications. We prescribe standards that applied to aircraft or ordnance equipment a number of years ago without giving you, the engineers, the opportunity to decide what *you* really needed to do the job. We have been guilty of long delays in making up our minds, and, then, after a great deal of this procrastination, we have frequently changed our minds overnight. Apparently both you in the industry and we in military service must make every possible effort to eliminate as many money-consuming practices as possible, and we must not do it independently but rather together. What can we do?

"First, and most important, we must think of cost from the very beginning of any design. Imagine that you have to go out and sell each missile separately and that the buyer is known to be a penny-pincher. I am convinced that, without sacrificing performance or reliability, we can all work toward the common goal of getting our prices down to a reasonable level.

"Second, we must strive to arrive at early component specifications. Too often we have gone through the agony of having to completely repackage and partially redesign a missile because the master mechanic was never consulted during phase and suddenly the engineer very proudly handed him a can of worms and said, 'Let's go into production.' The man who builds the missile must come into the picture as near the beginning as possible, and his suggestions must be listened to.

"Third, we must eliminate all the frills that we can. These are more prevalent in the supporting equipment and in the intangible expenses involved in missile procurement than they are in the missiles themselves.

"Fourth, we must make an effort to put the human being back in the missile loop wherever we can. There are many tasks which a man cannot perform with these modern weapons, but there are many that he *can* do as well as a little black box can.

"Fifth, in missile development phases we should be constantly looking for ways to reduce the number of unnecessary parts, to utilize already designed parts, and to reduce production costs. Our price consciousness must extend back beyond the missile itself. Obviously, a missile constructed of expensive parts will be expensive. We must start with components and must spread the gospel to our subcontractors.

"Sixth, we should employ cost experts in the same manner that they are now employed by manufacturers of devices that must compete for a public market largely on the basis of price. I realize that all producers of missiles employ efficiency experts of one type or another, but the time has come when these men should be as vitally concerned with the initial development of a missile as the engineers themselves and should be concerned with every stage of missile design."

Admiral Clark reported on five missiles in use: the air-to-air Sidewinder and Sparrow, the Terrier (on two ships), the air-to-surface Petrel, and the surface-to-surface Regulus I. Talos and Tartar, he said, are due soon and will strengthen air defense capabilities, and the new Regulus II is in the test state. Polaris, to become a fleet IRBM, was listed as due in a few years.

Lt. Gen. James Gavin, USA

Chief, Research and Development, Department of the Army

General Gavin, augmenting his presentation with motion picture films and slides which illustrated Army-industry relationship for progress, declared that the Department of Defense has a "far-seeing, comprehensive missile program." In this connection, he reported:

"The Department of Army has authorized me to announce today that we are producing a new deadly accurate guided missile for close tactical support of ground troops in the field—the La Crosse. La Crosse is an all-weather guided missile capable of destroying enemy strong points in the field to supplement air or artillery attack. It is propelled in flight by a solid fuel rocket motor."

The General then revealed that the La Crosse was designed and developed by Cornell Aeronautical Laboratory, Inc., and that The Glenn L. Martin Company will participate in its final development and in the production engineering phase. A film sequence on the missile was shown.

General Gavin predicted enough fighting for all in the next war and said that he welcomed interest in the missile field. On the "occasionally expressed concern about competition," he said that he felt it was a "healthy thing," adding that it "is the essence of the American system, and, as long as it is not allowed to become harmful in interservice relationships, it is a good thing and it should be encouraged."

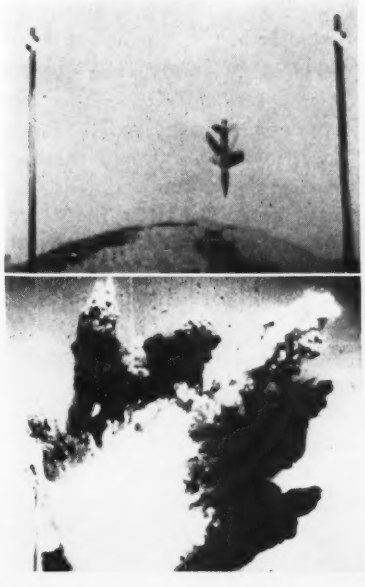
The General promised to give "every possible assistance" to the other military services and said that the Army last year "spent quite a few million dollars in direct support of a Navy missile program." He added that the Army currently "is also providing practically all the solid propellant now in use."

General Gavin said that it has been the Department of the Army's policy to strive continuously to place the bulk of its work with industry, citing as an example, "during the past year 86 per cent of the Army Ballistic Missiles Agency's procurements were with private industry. These amounted to more than $80 million."

Missiles discussed by the General included the Corporal, "the only operational surface-to-surface ballistic guided missile in the free world today"; Honest John, a free rocket; Little John, supplemental to Honest John; Redstone, a medium-range surface-to-surface guided missile; Dart, an antitank missile; Nike-Ajax, "our most effective operational land-based surface-to-air missile"; and La Crosse.

General Gavin declared it is the Army's belief that "the most important factor in successful missile development, assuming a high quality of individual skills, is that of teamwork." He said that he hoped to leave with his listeners the scope of the Army's missile program and added, "The development and production of

The La Crosse is shown poised on a launcher, mounted on a standard Army truck, then approaching and exploding on a simulated target at the Army Proving Ground, White Sands, N.M.



such missiles represents the highest degree of cooperation between the Armed Forces and American industry."

Major Gen. Bernard A. Schriever, USAF

Commander, Western Development Division, ARDC

General Schriever told the packed ballroom that "the Air Force's ballistic missiles program represents an effort of unprecedented scope and intensity on the part of the most competent and widespread team of government, science, and industry ever assembled on a single project." He said that this had resulted in all major development milestones for the Atlas and Titian intercontinental and the Thor intermediate-range ballistic missile programs being passed on schedule, adding, "Thus, a broad foundation has been created for U.S. leadership in ballistic missiles—a foundation which may also serve to assure U.S. leadership in future space technology."

General Schriever said he wished to make the following points clear:

"First, we are still a long way from the push-button type of warfare. The guided missile, as a weapons category, is still in its infancy and subject to many growing pains.

"Second, there is no such thing as an all-purpose guided missile. Therefore, the military services must expend a great deal of effort in the development of the various types of missile required for effective employment in support of different military objectives.

"Third, the largest variety of missiles is required by the Air Force in view of the broad scope of its responsibilities with respect to aerial warfare.

"Fourth, utilizing the vast facilities of the ARDC's centers and the tremendous resources of the ARDC-industry team, the Air Force is making steady progress toward the operational readiness of an increasing variety of special-purpose missiles.

"Fifth, the Air Force has already in its inventory several types of guided missile which are available in quantity for immediate use if necessary."

The General said that the air-to-air Falcon, a guided aircraft rocket, is "a very effective operational missile" and that the subsonic surface-to-surface Matador (operationally deployed in Europe), while one of the Air Force's oldest missiles, "is by no means obsolescent."

The surface-to-air Bomarc, a pilotless interceptor near operational readiness embodying considerably greater range than other surface-to-air weapons in operational use, was described as "the most promising air defense weapon system in the surface-to-air class."

General Schriever described the Rascal, still under development, as an example of an air-to-surface missile. It will be air-lifted to within a safe distance from enemy defenses then launched toward a tactical or strategic target.

He said that the surface-to-surface Snark, subsonic for several thousand miles, is the first intercontinental missile to enter the flight-testing stage and is close to operational.

General Schriever reported that the Navaho, also an intercontinental surface-to-surface guided missile but with supersonic and high-altitude abilities, is in the "advanced stages of development."

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Common System Standards *(Continued from page 95)*

tive standards is absolutely required. For example, I would suggest that a dual pulse return from the aircraft with a microsecond per thousand feet altitude—or what have you. I do not think this can simply be added later to a system of simple response.

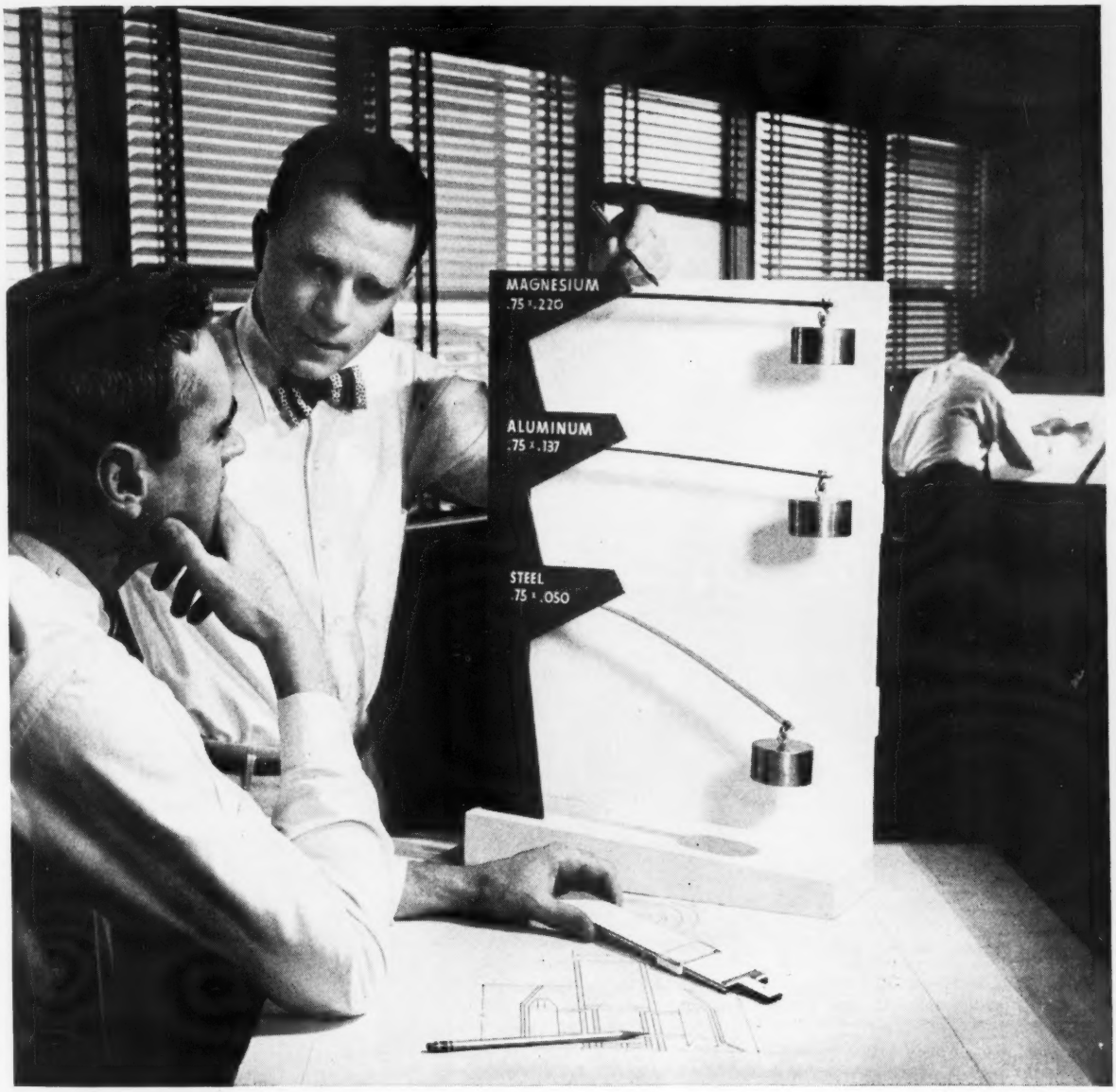
Again, I would suggest that the ground equipment be provided with a special challenge signal so that aircraft in a sector would automatically stop sending altitude information and send a single identification signal, then returning to the regular altitude response. But a system which used both altitude and identification on every challenge would be wholly different—and would certainly saturate a single frequency faster.

But a tentative standard would solve the problem during early development. As stated before, once someone who has no standard except his own ideas has developed his interpretation of what is needed, he must defend it with all his might against change. He has a financial stake which he properly defends since no one has set a standard but has merely tried to change his.

Conclusion

We could go on at great length into more complicated navigation elements, cover the matter of tolerances as they relate to each number adopted in a standard, and point out that tolerances of different magnitude can exist under a standard with the differentiation being in allowable procedures based on the user's equipment. But I will simply say this: Look behind each of the engineering specifications in existence in our field today. See if there is a real standard behind them, or whether they are simply companion specifications without too strong a tie between them. When you have done this, you will see that the adoption of really basic air industry standards is one of the chief bottlenecks today which make progress in air traffic control and navigation so difficult.

If we lend support to the early establishment of technical standards, we may enter the jet transport age with assurance of steady progress in the important matter of air traffic control, if nothing else. Let us turn our mysterious black boxes in the future with cellophane clarity instead.



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YOU CAN DEPEND ON DOW

Corporate Member News *(Continued from page 55)*

$12 million maintenance hangar at New York International Airport for the firm.

• **Arma, a division of American Bosch Arma Corporation,** has developed a small, lightweight, air-borne searchlight with a maximum light output reported to be 130 million c.p. Military designation for the light is AN/AVQ-3.

• **Bell Aircraft Corporation** has announced that the Bell Automatic Carrier Landing System has successfully completed all land trials and will be installed on a carrier soon for tests under actual carrier flight conditions. The system, developed for the Navy Bureau of Ships, is a combination of radar and radio that operates in all kinds of weather, the firm reports.

• **Boeing Airplane Company** has announced plans to use Seattle production facilities for manufacture of the firm's Bomarc pilotless interceptor. The Bomarc program has involved a network of subcontractors and suppliers with limited support from the firm's Wichita Division.

• **Bristol Aero Engines Limited** has announced that its Olympus 6 turbojet has completed an officially observed 150-hour run under type test conditions at the design rating of 16,000 lbs. thrust and has been stripped for inspection with a view to issuance of the official type of test certificate.

• **Chance Vought Aircraft, Incorporated,** announced that its Regulus I has made its five-hundredth flight.

• **Douglas Aircraft Company, Inc.,** has developed a new integrated-torso flight suit for the A4D Skyhawk which the Navy has accepted as standard equipment. The lightweight suit incorporates into a single garment a life jacket, parachute harness, seat belt, shoulder strap, and oxygen equipment. . . . The firm also has developed a self-contained refueling unit which, it claims, will permit quick conversion of Navy fighters and attack bombers into aerial tankers. The unit is a compact torpedo-shaped package, 17 ft. long, powered by a ram-air turbine driven by a four-bladed propeller in its nose. The refueling store contains hydraulic motors, fuel pump, a flexible hose on a reel, a collapsible drogue, and fuel. Carried under the fuselage of Skyraiders and Skyhawks, it can be jettisoned in an emergency.

• **Fairchild Engine and Airplane Corporation,** Engine Division, announced plans for construction of a Supersonic Combustion Laboratory at Deer Park, L.I., N.Y. The new lab will be used for experimental work in aerodynamics and thermodynamics. . . . The firm's headquarters announced receipt of an order for three F-27 prop-jet transports from Southwest Airways Corporation. . . . The Aircraft Division reports that C-123's were used tactically for the first time when they parachuted personnel and equipment from the Army's 101st Airborne Division during a training exercise in Kentucky.

• **Federal Telecommunication Laboratories, Division of International Telephone and Telegraph Corporation,** has published a new brochure describing research and development activities in the fields of radio navigation and communication, guided missiles, electronic counter-measures, solid-state physics, vacuum tubes, weapon control systems, and data processing.

• **The Firestone Tire & Rubber Company** has announced a program to design, build, test, and install a guided-missile launching system for submarines.

• **General Dynamics Corporation,** Convair Division, has announced plans for construction of a new 100,000-sq.ft. structure to be leased for off-site engineering office space. Some 1,700 Convair-Fort Worth engineering department employees will occupy the new building.

• **General Electric Company's** Research Laboratory has developed a new material, cubic boron nitride, that will scratch a diamond and withstand twice the heat it takes to burn a diamond. Named Borazon, it was discovered by Robert H. Wentorf, a physical chemist. . . . Scientists at the Aircraft Gas Turbine Division, Flight Propulsion Laboratory, have developed a closed-circuit TV camera about twice the size of a cigar box to reduce development time of jet-engine control systems. . . . The division announced that the first application of the Aircraft Accessory Turbine Department's fuel-air combustion starter for jet engines will be on the McDonnell F-101B Voodoo. . . . The division's Production Engine Department has reorganized its Marketing Section research and administration activities into two separate functions known as Marketing Research & Business Planning and Marketing Administration. . . . Defense Electronics Division, Missile and Ordnance Systems Department, has created sustained temperatures of 25,660°F. with a water-stabilized electric arc.

This cageable vertical gyro manufactured by Minneapolis-Honeywell Regulator Company, Aeronautical Division, features a new synchro design that reportedly allows for high accuracy under actual operating conditions. The synchro design was developed in cooperation with Magnavox. It is the firm's first cageable gyro to use a synchro rather than a potentiometer for gimbal displacement measurement.

• **Giannini Research Laboratory** has developed a plasma jet (mixture of gas and electrically charged particles) which can maintain a temperature of more than 10,000°K. The plasma may be accelerated by the addition of heat and magnetic fields and, under proper conditions, may achieve velocities in excess of those attainable with chemical propellants used in conventional reaction devices, the firm reports.

• **The B. F. Goodrich Company** has a stainless-steel De-Icer which generates heat like an electric toaster. The unit is being used in the horizontal stabilizer of the Boeing KC-135 tanker-transport.

• **Grumman Aircraft Engineering Corporation** has announced flight of the prototype WF-2, a radar, "saucer-topped" early warning aircraft. The aircraft is a modification of the passenger-cargo TF-1 Trader.

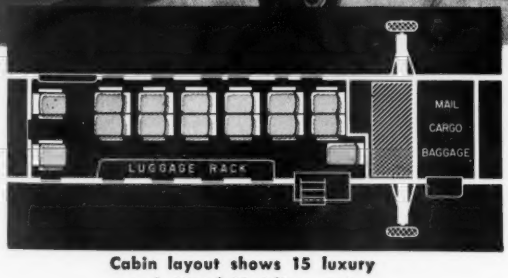
• **Lear, Incorporated,** has opened a New England office at 993 Farmington Ave., West Hartford, Conn., to provide closer liaison with customers and expedite expanding business in the area. Manager

Bell Aircraft Corporation's supersonic GAM-63 "Rascal" missile is designed for use with manned bombers as an aid for penetrating enemy defenses. It has been launched from B-47, B-36, and B-50 bombers during flight tests at Holloman Air Development Center, N.M. It is shown on the carrier that is used to move it on the ground and load it into carrier aircraft.

New Vertol helicopter seats 19 passengers, doubles as freighter

For the first time, a large capacity helicopter, the Vertol 44, is available to commercial operators. And it comes with a selection of interiors suited for airline operation, executive transportation, or combination passenger-freight use.

Based on the design of the famous Vertol H-21, which has been flown more than 100,000 hours by the military services of the United States, Canada, France and West Germany, the Vertol 44 offers the versatility and cabin capacity long lacking in civilian helicopter operation.



Cabin layout shows 15 luxury seats in Vertol 44 airliner version.

Engineers, if you are not already working for the government or defense industry, investigate job opportunities with Vertol.

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- Better high altitude performance with two-speed engine supercharger.

For detailed information on the Vertol 44 write to:
Customer Relations Manager

VERTOL *Aircraft Corporation*

MORTON, PENNSYLVANIA

A B-58 "Hustler" with the detachable "pod" carried under its fuselage is shown in its first view by Convair, A Division of General Dynamics Corporation. The firm reports that the Hustler's stilt-like landing gear was designed to keep the pod from scraping along the runway. The purpose of the pod was not revealed.

of the office is John Vlad. . . . Lear-Romec Division has developed a fuel booster pump Model RR11530D1 designed for pumping fuel per Mil-F-5572, Grade 115/145. The division reports the pump is rated at 4,000 lbs. per hour at 16 psi for normal duty and 4,000 lbs. per hour at 25 psi nominal for emergency duty.

• **Lockheed Aircraft Corporation,** Missiles Systems Division, has announced that its engineering and research activities are being integrated under a new Research and Development Branch. Willis M. Hawkins (M), current Director of Engineering, will become an Assistant General Manager of the division. Louis N. Ridenour, Director of Research, will head the new branch. . . . The firm also disclosed a new pilot ejection seat designed to permit safe escape from aircraft traveling 1,500 m.p.h. The firm calls it a parachute-equipped "flying seat" with complete aerodynamic stability and windblast protection. . . . Georgia Division has delivered the last B-47E Stratojet to the Air Force.

• **Manning, Maxwell & Moore, Inc.,** has published a new catalog on "Hancock" bronze and steel valves. Designs include globe, angle, gate, "Flocontrol," and other types applicable to power, petroleum, chemical, and general industry installations.

• **The Glenn L. Martin Company** has cosponsored with the Office of Naval Research a Colloquium on Radiation Effects on Materials at The Johns Hopkins University.

• **Minneapolis-Honeywell Regulator Company** has published a new booklet with photographs and a detailed list of variations and specifications for most of the major hermetic integrating, rate, and cageable vertical aeronautical gyroscopes manufactured by its Aeronautical Division.

• **North American Aviation, Inc.** . . . Columbus Plant has developed a contact printer which can reproduce templates up to 30 ft. in length. . . . Autonetics Division engineers have developed a transportable, midget computer "Recomp," which adds, subtracts, multiplies, and divides faster than the familiar desk calculator, according to the firm. First model of the all-transistor digital computer has been delivered to the Air Force Rome Air Development Center. . . . Division engineers also have devised a transistorized antenna switch that automatically selects exposed antennas and reportedly assures uninterrupted in-flight communications. Its classification is Selector Antenna C-2193/ARC.

• **Northrop Aircraft, Inc.,** has put into use a missile engine test cell building whose design permits sound energy to be transformed into heat energy. The firm reports that noise of a jet engine running at full throttle is reduced 98.5 per cent by the new method. . . . The firm's Board of Directors has approved a major refinement of its corporate structure to establish company operations under a line division structure. The streamlining will tailor Northrop's organization to major programs which will occupy the company in coming years. . . . An industrial helicopter "air line" has been set up by the firm to carry passengers and urgent mail between its Southern California plants. A Bell 47-J four-place helicopter is making twice-daily flights between Hawthorne, Van Nuys, and Anaheim.

• **Pan American World Airways, Inc.,** plans to install a coast-to-coast automatic reservations system manufactured by Teleregister Corporation. Installation is expected to be completed this month.

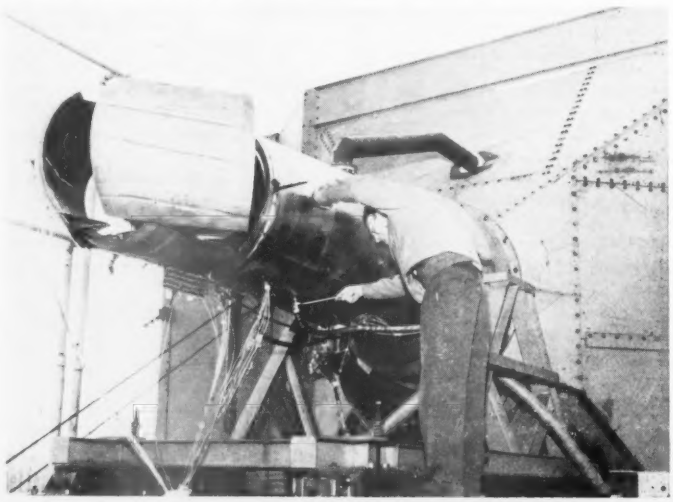
• **The Parker Appliance Company** has announced two new distributers of Parker synthetic rubber O-rings. They are Wencor, Inc., P.O. Box 391, Miami Springs, Fla.; and Industrial Piping Supply Corp., 705 N. 22nd St., Bessemer, Ala.

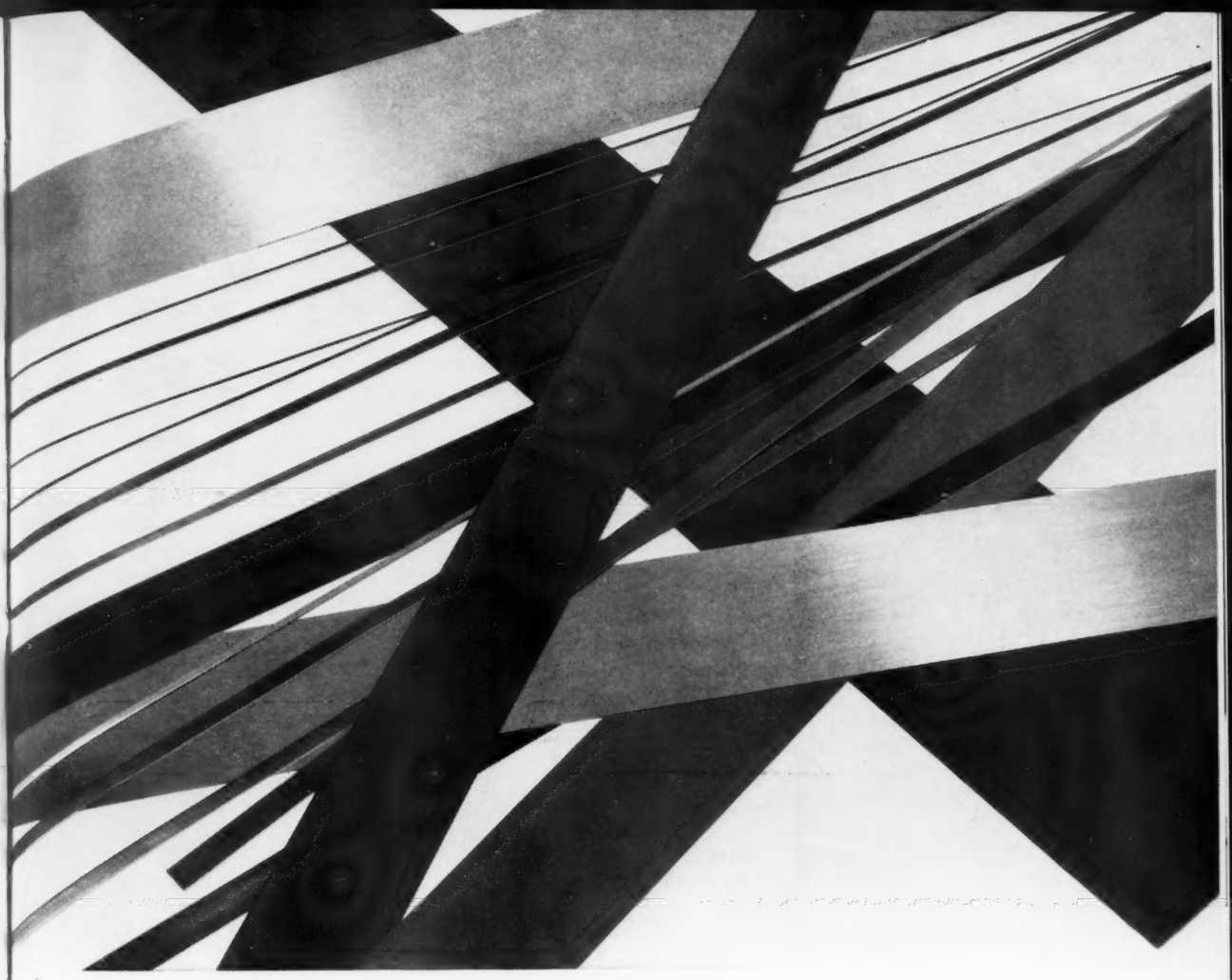
• **Republic Aviation Corporation** has developed a radio frequency spectroscope that, according to the firm, detects and eliminates interference in radar, communication, and navigation systems of newly built jet fighter-bombers. The device is basically a hypersensitive radio set that is plugged into an aircraft's antenna and "hears" any interference or static when the ship's various electrical systems are operating.

• **Ryan Aeronautical Company** reports its Firebee jet drone target missile has soared to 53,000 ft. and remained in the air on remote control for 1 hour and 44½ min. The experimental Firebee was controlled by a new autopilot developed by the firm and was powered by an improved Continental J-69 turbojet.

• **Solar Aircraft Company** is developing a 1,000-hp. gas-turbine engine for both military and civilian use. The firm says the new engine will be called the Saturn, will be both lighter and smaller than current 500-hp. turbines, and will have a fuel consumption lower than any gas turbine in its power range. The engine will

Curtiss-Wright Corporation's newly developed jet-engine thrust reverser will reportedly reduce landing roll distances as much as 50 per cent. Made by the firm's Propeller Division, it can be fully modulated—precisely controlled by the the pilot for any per cent of thrust, from full forward to full reverse. Actuating time for the full cycle is less than 2 sec. Two integral streamlined panels use the air-frame structure to form the reverser.





How these "educated" steels make products behave better

• Nobody will deny that there can be a vast difference between steels that are supposedly alike. The difference lies in "tremendous trifles" that often make all the difference between smooth and erratic fabrication or between satisfactory and faulty product behavior.

That's why the steels shown above are "educated", you might say—educated for special use. Because here at the *Athenia Steel Division* of National-Standard we've concentrated for years on learning about and *controlling* those tremendous trifles! In turn, this learning and experience is put right into the Athenia steels that successfully meet many of the toughest assignments known today.

If your production calls for cold rolled flat steels of .45 carbon or higher, from .015" to 16" wide and from .001" to .065" thick, it would be a good idea to explore Athenia quality, performance and service.

NATIONAL NS NATIONAL-STANDARD Company NILES MICHIGAN **STANDARD**

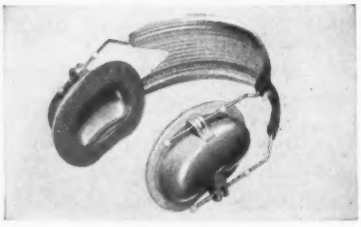
DIVISIONS: NATIONAL-STANDARD, Niles, Mich.; *tire wire, stainless, music spring and plated wires* • **WORCESTER WIRE WORKS, Worcester, Mass.;** *high and low carbon specialty wires* **WAGNER LITHO MACHINERY, Secaucus, N. J.:** *metal decorating equipment* • **ATHENIA STEEL, Clifton, N. J.:** *flat, high carbon spring steels* • **REYNOLDS WIRE, Dixon, Ill.;** *industrial wire cloth*

TURNS "JET BLAST" INTO A WHISPER

You stand within a few feet of a blasting jet engine, but your hearing is protected from an ear-splitting roar that under ordinary circumstances would be intolerable and perhaps cause permanent hearing loss.

The reason is RCA's *Ear Protector*, a new and scientific approach to the problem of excessively loud noise. This device dampens out intense and penetrating sounds, permitting you to work comfortably in areas where-in the noise levels might otherwise be prohibitive.

Made of plastic, the Ear Protector surrounds the ear without actually touching it. Contact with the head is by means of a soft, replaceable, liquid-filled cushion that provides a comfortable, self-adjusting seal. It may also be adapted for intercom use, and for any other application where noise can interfere with efficiency.



Light in weight, highly efficient, sanitary, simple and inexpensive, RCA's Ear Protector belongs wherever noise becomes a menace or a nuisance.

Defense Electronic Products

RADIO CORPORATION of AMERICA

Camden, N.J.

Tmk(s) ®

be specifically designed for marine propulsion.

• **Sperry Gyroscope Company Division of Sperry Rand Corporation** has announced plans to produce special propellant-driven guidance and control devices for guided missiles. The company is building a propellant devices laboratory adjacent to its Nassau County, N.Y., facility for initial work with solid propellants. Liquid propellant work also is contemplated.

• **Thiokol Chemical Corporation** has published a portfolio on butyl rubber developments. The kit contains latest information on market developments on butyl rubber; a technical bulletin on evaluation of butyl accelerators (sulfur-type cures); and a study of carbon black in butyl rubber, according to the firm.

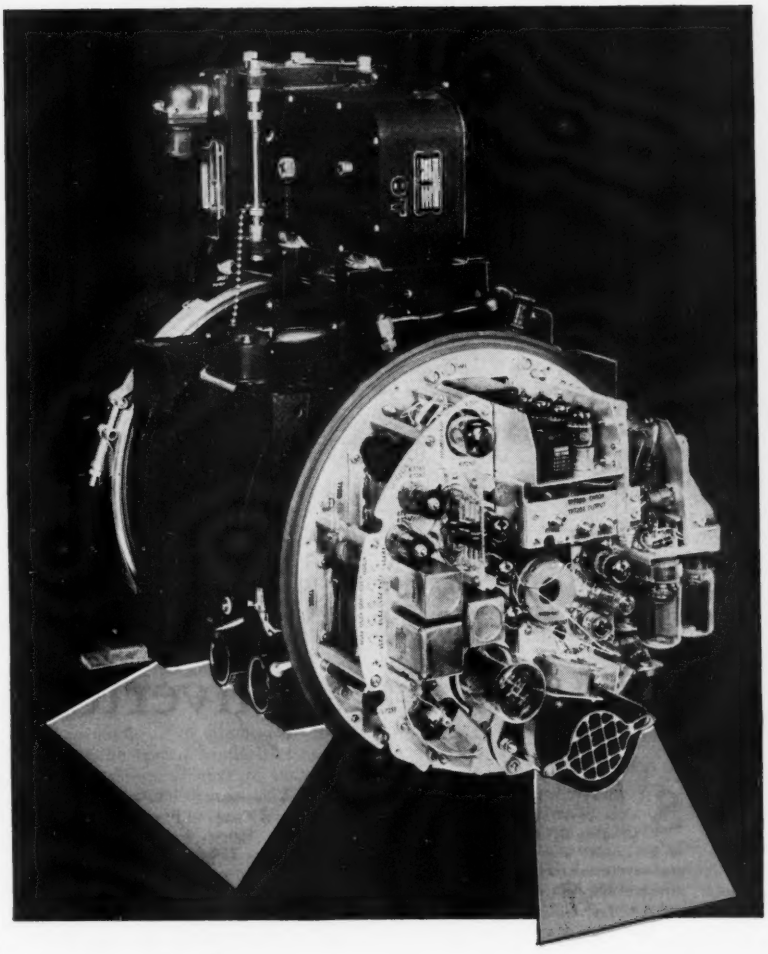
• **Union Carbide and Carbon Corporation** ... National Carbon Company division has developed what it calls the smallest battery of its type to be mass produced. First application of the Eveready W-307 energizer will be in an electric wrist watch, but the firm believes it should satisfy demand for a miniature "power plant" for other electrical devices. The battery weighs 1/20 oz., is 0.440 in. in diameter, and 1/8 in. thick. Nominal voltage rating is 1.5 volts.

• **United Air Lines, Inc.,** has announced plans for expanding facilities on a 40-acre site at San Francisco International Airport. Plans include a hangar, flight kitchen, employee cafeteria, washing facility for aircraft, and a line maintenance area with underground fueling system.

• **United Aircraft Corporation** ... Pratt & Whitney Aircraft Division has formed a nuclear engine program as a separate operation of the division. The new department will be called the Connecticut Aeronautic Nuclear Engine Laboratory (CANEL) and will have its own general manager and engineering staff. Operations will be conducted at a new Air Force-sponsored facility in Middletown, Conn., which the company will occupy this summer.

• **Vickers Incorporated** has announced a new hydraulic starter package for aircraft turbine engines which also may be used for auxiliary or emergency hydraulic power. Starter power source is a lightweight, air-cooled gasoline engine which drives a Vickers variable displacement pump. ... The company's decentralization program has created four additional operating divisions—Aero Hydraulics, Machinery Hydraulics, Mobile Hydraulics, and International. ... The firm's new plant in Jackson, Miss., has begun manufacturing of air-borne hydraulic systems and components. ... A new regional sales office has been opened at Albertson, L.I., N.Y., to provide application engineering and service assistance to users of aircraft oil-hydraulics in northeastern United States and Canada.

• **Western Gear Corporation** ... Electro Products Division has announced the design and availability of a miniature gear head motor. Specifications are 115 V.-D.C., output speed 12.5 r.p.m., and gear current drain 100 milliamp.



Joy Fans HELP LICK HIGH VOLTAGE ARC-OVER IN AIR-BORNE RADAR UNIT

WHEN MOTOROLA designed this 10 inch air-borne radar indicator to operate at 60,000 ft. they eliminated high voltage arc-over by pressurizing the unit. But this created excessive heat.

TO DISSIPATE HEAT an air-to-air heat exchanger, using three Joy Axivane fans was built in. Two external fans blow outside air between two plates separated by aluminum tubing. Another Joy fan, sealed *inside* the pressurized radar unit circulates hot inside air thru this tubing.

THESE JOY FANS must operate in the wide temperature range of —55°C to +125°C ... tough treatment.

Joy has over 250 models and 1300 designs of these high performance fans ready to solve your toughest air-moving problem ... be it electronic cooling, de-icing and defogging or ventilation. Write *Joy Manufacturing Company, Oliver Building, Pittsburgh 22, Pa.* In Canada: *Joy Manufacturing Company (Canada) Limited, Galt, Ontario.*

Write for FREE Bulletin 14 -2

WSW I 6415-143

JOY ... EQUIPMENT FOR AVIATION ... FOR ALL INDUSTRY

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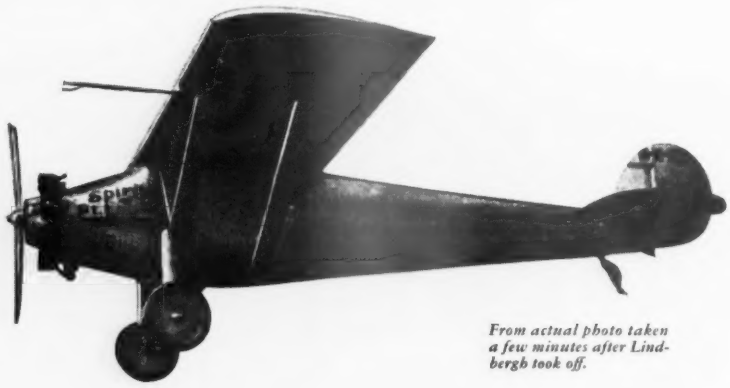


From actual photo taken a few minutes after Lindbergh took off.

LINDBERGH Lands in Paris on Goodrich Silvertowns

SILVERTOWNS across the sea! Landing on the dependable resilience of Silvertown Airplane Tires, Capt. Charles E. Lindbergh in his Ryan monoplane "Spirit of St. Louis" won his fight with death and distance. The stalwart cushioning of Silvertowns absorbed the landing shock of the first airship to fly from New York to Paris without a stop.

Silvertowns started Lindbergh safely on his way past the dangerous, critical seconds of the take-off at New York.

Silvertowns delivered him safe at Paris — safe from the fateful impact as his eagle plane swooped from the sky, and slammed its wheels down on Europe.

The first thirty seconds of the flight — the last thirty seconds of it!

The first 1,000 feet on the ground after Lindbergh cried "Okay" and they jerked the chuck blocks away from the Silvertown-shod wheels! The last 1,000 feet as the great monoplane hurtled across the Paris landing field.

These were seconds of held breath and tense nerves. Would the tires stand up as the 5,150 pounds of the loaded plane hammered and battered them along the runway? Would they hold the 46-foot wingspread of the eagle ship true to the course?

Would a tire fail in those seconds of grave stress? A blowout spelled the end of the magnificent venture, perhaps with a still greater adventure for the man in the cockpit.

Less than a minute of time, yet an eternity of suspense, the overseas plane thundered along the gauntlet of disaster.

Silvertowns held! Their sinewy strength, their sturdy cushioning stood the stress and strain that had doomed a thousand flights. Capt. Lindbergh soared away safe and landed safe.

Silvertowns met the test as they met it when this unheralded challenger, Capt. Lindbergh, started on his flight from San Diego to New York and made it in less than twenty-three hours.

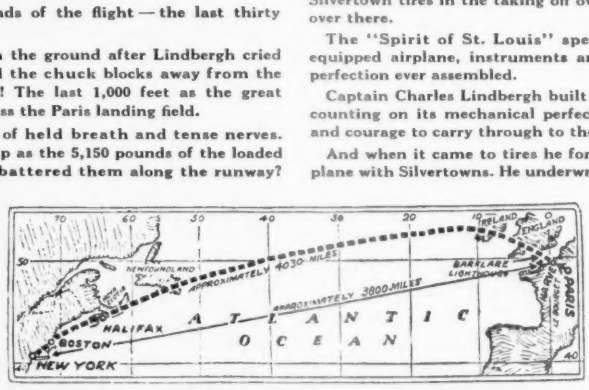
The dash through the clouds to Paris was a matter of gasoline, courage of the intrepid voyager of the skies — and Silvertown tires in the taking off over here and the landing over there.

The "Spirit of St. Louis" sped overseas a perfectly equipped airplane, instruments and parts the nearest to perfection ever assembled.

Captain Charles Lindbergh built it quietly at San Diego, counting on its mechanical perfection as well as his skill and courage to carry through to the goal.

And when it came to tires he fortified the security of his plane with Silvertowns. He underwrote the safety of his venture with the tires that have through years met the test of great moments of competition.

He called to his aid the same flexing strength, the same dependable endurance with which Goodrich Silvertowns have for years served the motor cars of the world.



The B. F. Goodrich Rubber Company, Akron, Ohio

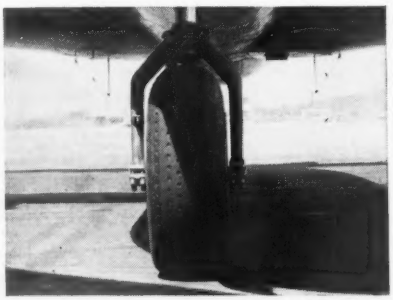
Goodrich Silvertowns

BEST IN THE LONG RUN

This ADVERTISEMENT appeared in June, 1927

Now pilots land all over the world on B. F. Goodrich Tubeless

THE MOST SIGNIFICANT development in tires since Lindbergh's flight is Tubeless, pioneered and patented by B. F. Goodrich. Now in service with overseas airlines and military planes, B. F. Goodrich Tubeless sets the pace because it saves weight, performs better.



B. F. Goodrich Tubeless Tires are making greater payloads possible by reducing weight as much as 120 pounds per plane. And while saving weight, BFG Tubeless Tires offer superior air retention, save time and money in warehousing and maintenance. That's why the trend is to B. F. Goodrich Tubeless.

B. F. Goodrich Tires "cross the Atlantic" again on a replica of the SPIRIT OF ST. LOUIS in the Leland Hayward—Billy Wilder motion picture production of Charles A. Lindbergh's Pulitzer Prize-winning story, "THE SPIRIT OF ST. LOUIS"... with JAMES STEWART as Charles A. Lindbergh, presented by WARNER BROS.

B.F.Goodrich

AVIATION PRODUCTS

A division of the B. F. Goodrich Co.
Akron, Ohio

• **Westinghouse Electric Corporation** scientists have developed a new high-strength, high-temperature metal designed to help push back the "heat barrier" encountered by jet engines. The new metal is intended as a structural material for use in the turbine section of jets. It is an alloy of iron, nickel, chromium, molybdenum, titanium, and boron. Classification is W545. . . . The firm also has announced availability of a new magnetic core, Hipermag, for magnetic amplifier reactors, transductors, current transformers, and other magnetic devices.

• **Weston Electric Instrument Corporation** has announced availability of Vamistors in resistance values up through 1 megohm. The firm reports that these units are virtually impervious to the effects of abrasion, thermal shock, and temporary overloads through use of a special resistance alloy fused in a dispersed form into the inner surface of a moisture-sealed ceramic tube.

IAS SECTIONS

Submarines Also "Fly"

Boston Section

"Aircraft Engineering and Small Submarines" was discussed by T. F. Hammen, Jr., at the February 19 meeting. Mr. Hammen is Assistant Chief Engineer, Fairchild Engine and Airplane Corporation, Engine Division. He has direct supervision over the X-1 small submarine development.

For an audience of mostly aeronautical engineers, he traced similarities and differences in design of aircraft and submarines. Both vehicles are propelled through a fluid, he said. The greatest difference between them is the density of the fluid and the speed of the vehicle. Design relationship was traced in parallel in fields of drag and propulsion, structures, stability and control, and general arrangement.

Drag components of the two vehicles have much in common. Both suffer from friction drag, form or pressure drag, induced drag (a minor contribution in submarines), and trim drag. Wind tunnels are used for measuring aircraft coefficients, water tunnels for submarines.

The problem of form drag in submarines is given much attention where hull shape is concerned and may be compared with the problem of obtaining laminar flow over a wing.

A special problem of submarine design is cavitation. This concerns drag arising in the determination of the blade geometry of propellers. It does not occur in aircraft propellers.

Mr. Hammen pointed out that, in general, gust and maneuver loads determine aircraft structures, whereas depth pressure determines submarine structures. To a minor extent, wave action on the surface will determine the required strength of superstructure and controls. Both submarines and aircraft must have circular hulls—submarines because of depth pressure and aircraft because of altitude pressure. A stiffened shell structure is used in submarines just as in aircraft.

Weight is important and receives much consideration during preliminary design. Light-metal alloys are used in superstructure and other appendages wherever possible. The safety factor for submarines is 2.0 compared to 1.5 in aircraft.

Both static and dynamic stability are important, although the submarine has special problems, in surfacing or on the surface, which do not arise in the aircraft. On the surface submarines are less stable than other vessels and are sensitive to roll stability. Submerged, they "fly" on "instrument flight rules" using a central control station and control console, which are similar to aircraft flight decks, including the standard wheel and yoke for directional changes.

Submarine engineers give much attention to the habitability of the vessel, akin to the problem of housing a flight crew in long-range bombers. Atmosphere and temperature controls are vital—pressurization is necessary in aircraft, carbon dioxide control in submarines. Duration of cruise or flight determines weight and space that must be allocated for habitability items. In both vehicles escape means are needed, and their reliability is vital to the crew. Automation in control for the vehicle and its weapons would be advantageous in morale and in reducing the skill needed to fly and fight the vehicle. Aircraft methods have been used extensively in mounting power plants, machinery, and in acoustic treatment of submarines.

Mr. Hammen said he thought future emphasis in submarines could be placed on speed. Drag may be reduced by improving hull design and retracting superstructure and other appendages. Better propulsion systems will improve speed, and better structural methods will reduce weight and improve performance.

He said the aeronautical engineer can effectively assist in these developments because of his experience in similar cases. By the same token, he can learn extensively from the submarine engineer, especially with reference to nuclear power plants and the problem of habitability.

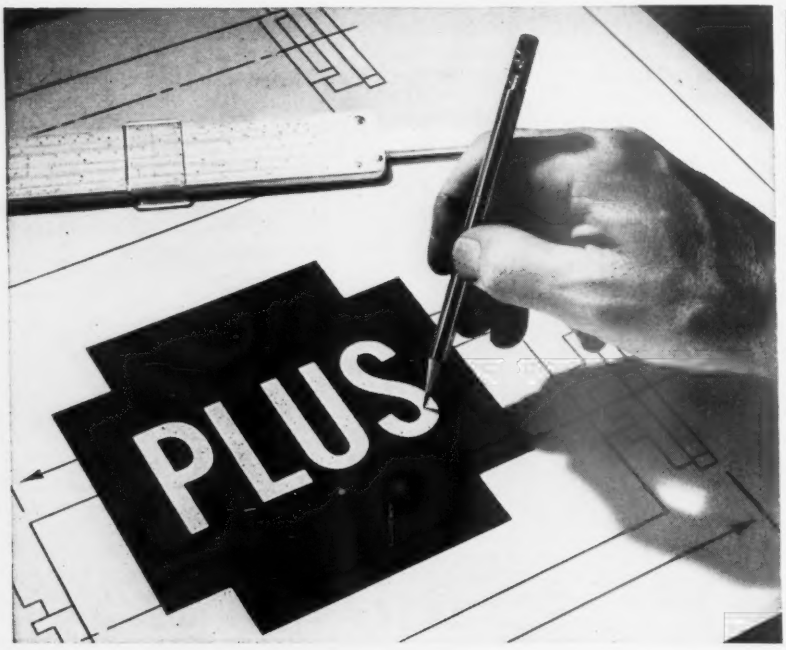
He illustrated his talk with slides and a color film of the X-1 during preliminary fleet trials.

DANIEL J. FINK, *Secretary*

Man in Space

Cleveland-Akron Section

Herman J. Schaefer discussed "Physiological Problems of Space Flight" before 120 members and guests at a joint meeting with the American Rocket Society. Dr.



Put the PLUS in your microwave systems with AIRTRON *FERRITE* devices!

Airtron has stepped well beyond conventional designs through the use of remarkable non-reciprocal ferrite materials to give you microwave components with characteristics never before realized in the microwave design art!

Such vast improvements as isolating action, duplexing action, polarization diversity, electronic phase shift, remote attenuation and R.F. modulation are now possible with ferrite components.

These and Airtron's other great advancements are the *plus factors* that will minimize long line effects . . . provide rapid switching . . . improve AFC performance . . . permit rapid receiver recovery time . . . optimize magnetron operation . . . and eliminate mechanical mechanisms. Too, Airtron ferrite components will strengthen the reliability of your radar and microwave systems by increasing the operational life.

Airtron has successfully developed ferrite materials to a practical stage of application in a wide variety of designs, such as resonant absorption isolators, duplexers, switches, electrically variable attenuators and phase shifters, modulators, polarizors, beam switching antennas, single side band generators and similar devices that are unparalleled in comparison!

***Add The Plus To Your Achievements** with superior performing ferrite components by Airtron! For more detailed information and assistance in solving your specific microwave or ferrite component problems, contact Airtron immediately.*

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P ERFECTION in design **L** ONGER life operation **U** NPARALLELED comparison **S** UPERIOR performance

Schaefer is on the staff of the U S. Naval School of Aviation Medicine, Pensacola, Fla.

He emphasized that the human system does not respond as a simple collection of tubes, bottles, and chemicals. As an example he cited the lungs which serve a multiple function. It is not sufficient just to maintain sea-level oxygen partial pressure to satisfy breathing requirements. Alveolar air contains considerable moisture and also an appreciable percentage of carbon dioxide. Therefore greater quantities of oxygen are needed as altitude increases.

The lungs, like a delicate mechanism, control the acidity of the blood as well as act as a blood purifier and oxygenator. This acidity balance is controlled by the partial pressure of carbon dioxide in lung recesses. When too little carbon dioxide is maintained in the lungs, the blood becomes alkaline and constriction of the blood vessels may follow along with a blackout condition.

When the carbon dioxide partial pressure is gradually reduced, the chemistry of the kidneys gradually alters to maintain the proper acidity of the blood stream. This explains why natives of the Andes can live comfortably at 18,000 ft.

Dr. Schaefer also discussed problems associated with high acceleration, rapid decompression, the toxicity of ozone, lack of gravity, cosmic rays, and other sources of danger to the human being who might fly in space.

He concluded with a movie on mice and monkeys, passengers on Aerobee rockets that were recovered.

JOHN C. EVVARD, *Secretary*

Dayton Section

James R. Kessler spoke on "Ram Air Windmills for Emergency Aircraft Power" at the February 19 dinner meeting. Mr. Kessler is associated with the General Motors Corporation Aeroproducts Division.

He said these windmills absorb energy from the aircraft's slipstream and convert it into shaft horsepower. A generator or pump, or both, is coupled to the windmill and, in turn, supplies usable energy for operation of equipment. Units vary in size from 9 to 23 in. in diameter and deliver from 2 to 50 hp.

Existence of ram air units stems from the need for a lightweight, reliable source of emergency power when a pilot needs more energy to control the aircraft.

The ram air unit basically converts the kinetic energy of air passing through its disc in unit time to usable power. To tap this power properly, a variable pitch windmill with rotational speed control is needed. A simple fly-ball, droop-type governor is used, and good windmill performance has been experienced at high aircraft speeds.

Another use for the windmill is to supply operational power. A windmill could be the front of an externally stored tank and would supply power to operate refueling, electronic, or similar equipment installed in the tank. Other uses include application to missiles and high-speed aircraft.

"STAR JUGGLER," a new interpretation by Simpson-Middleman, painters of the meanings of science. "We began to portray a sun as a stationary nucleus of a cosmic atomic system," recounts this imaginative team of artists, "but as the work progressed, there emerged a sense of movement, a suggestion of a sun swinging planets through space until they approached the stars in brilliance." Painting courtesy of John Heller Gallery, Inc.

You'll find an extraordinary future at Boeing

If you are impatient with ordinary achievement, you'll feel right at home at Boeing. For here you'll work with engineers and scientists whose habitual custom it is to push toward the future in giant steps. To cite just two examples: the Boeing 707 jet airliner, which at a stroke cuts commercial flight schedules in half, bringing the Pacific and Atlantic coasts within four hours of each other; and the Boeing B-52, which reduced the dimensions of the earth to a nonstop flight time of 45 hours, 19 minutes.

Today Boeing engineers invite you to join them on projects that open out onto the still more extraordinary vistas of the future: advanced supersonic aircraft and guided missiles, electronic and inertial guidance, chemical fuel propulsion.

There are openings at Boeing now for engineers of ALL categories, and for physicists and mathematicians. You'll find the future—your future—at Boeing, today!

BOEING

Drop a note now to John C. Sanders, Engineering Personnel Administrator, Boeing Airplane Company, Department A-63, Seattle 24, Washington

Mr. Kessler said ram air units are having the usual problems that go with a new product, but they have a broad future and their development will be interesting to watch during the next few years.

W. E. STANGER, *Secretary*

Detroit Section

Some 350 members and guests attended a symposium on small gas turbines in the auditorium of the Engineering Society of Detroit on February 5.

Speakers and their subjects were D. C. Shepherd, Professor of Mechanical Engineering, Cornell University, on "Performance of Turbine Cycle Combinations"; Roy R. Peterson, U.S. Navy Project Engineering Gas-Turbine Program, Bureau of Ships, on "Application of Small Gas-Power Plants"; and Homer J. Wood, H. J. Wood & Associates, Consulting Mechanical Engineers, on "Basic Mechanical Forms of Power-Plant Layout." Moderator was E. T. Vincent, Professor of Mechanical Engineering, University of Michigan.

Professor Shepherd gave a quick review of the basic gas-turbine cycle to show the effect of temperature, regeneration, and intercooling. He related them to the limitations of various components and also brought out the advantages and limitations of the radial and axial flow compressors and turbines.

Mr. Wood explained four characteristic eras in the evolution of power plants. He commented on conception of the physical principle or working cycle; first development of a useful mechanical design embodying the principle; variation and adaptation in mechanical design producing a wide variety of shapes, sizes, and arrangements of components; and competitive reduction to relatively few forms of engines by "survival of the fittest."

Mr. Peterson showed slides and a movie to point out applications in which gas turbines have been used, regardless of their design motive. He said the gas turbine has proved itself a definite power plant and that its development depends upon actual fuel consumption in competition with prime movers.

A question and answer period was held after the talks.

FRED J. WILHOFF, *Secretary*

Pneumatic Components

Indianapolis Section

Seventy members and guests heard Edward J. Knight, Jr., speak on "Pneumatic Control Components for Jet Engines" at the February 11 dinner meeting. Mr. Knight is Assistant Project Engineer, Engine Controls, for the Garrett Corporation's AiResearch Manufacturing Company of Arizona.

He gave a short history of pneumatic control applications and discussed present and future trends. The expanding flight speed-altitude envelope of aircraft has created severe environmental conditions which present problems in thermal instability in hydraulic systems, he said. These cause destruction of insulation properties and other deleterious effects on electrical controls. Air provides an energy source which is not contaminated by high temperatures and which retains physical form over the entire range of environmental temperature experienced.

Mr. Knight illustrated his talk with examples of various pneumatic controls and systems.

Before Mr. Knight's talk, Chairman Robert L. Saff reported on the Section Chairmen's Meeting during the IAS Annual Meeting in New York.

JOHN A. DUFF, *Secretary*

Douglas Aircraft Company's El Segundo Division played host to 136 members of the Los Angeles Section at a visit to the division's facilities on November 28.

Los Angeles Section

E. H. Heinemann, Chief Engineer of Douglas Aircraft Company, Inc., El Segundo Division, welcomed 136 members of the Section to a visit of plant facilities on November 28.

After a general introduction, members split into small groups and were guided on an inspection of the A3D production line, the Engineering Building, and the Experimental Simulator Laboratory.

They saw a demonstration of the A4D fire power at the firing range and a static drop of the F4D in the Engineering Test Laboratory. Toward the end of the visit the groups were shown a static display of the A3D, A4D, and F4D.

Mr. Heinemann briefly summarized the division's history and answered numerous questions from the group.

Niagara-Frontier Section

Wilfred Dukes of Bell Aircraft Corporation spoke on "Design Trends in Future Aircraft Structures" at the February 13 meeting. Mr. Dukes is Chief, Structures Analysis Section, Bell's Research Division.

He began by dividing aerodynamic heat structural problems into two categories—the effects of heat on the characteristics of materials and the effects of temperature gradients which develop in the structure.

He said data for stringer-stiffened panels and multiweb wings indicate alarming increases in structural weight as speeds of Mach 4 and 5 are approached. The use of higher strength material (for high-temperature strength) is recommended to alleviate this problem. But, use of such material leads to thinner structural elements which become unstable and buckle easily when compression loads are applied. High-temperature materials make necessary better methods of stabilization against compression buckling. A significant development devised to overcome this problem is the use of sandwich materials. Creep, initially thought to be a major factor, was found to be relatively unimportant after a general investigation.

Examination of temperature gradient problems showed that the more desirable structure should consist of an outer shell which is uniform in mass, has compressive stability and load-carrying ability in all directions in the skin plane, but has a very small depth dimension. This shell can be attached to internal shear web or frame structures which are either flexible or in some way permit deformation. The use of sandwich in the skin panels satisfies many of these requirements.

Mr. Dukes described a method of construction using an insulated and cooled aluminum structure which analysis has shown to be satisfactory at speeds above Mach 3.5.

He applied recently developed analytical methods and new approaches to design to problems of the manufacturing laboratory, flight-test engineers, materials suppliers, and aerodynamicists. Some 50 members attended the meeting.

RONAL CRISMAN, *Secretary*

Test Satellites

Rocky Mountain Section

"The Scope of the IGY Program" was discussed by Walter O. Roberts at the December 7 meeting. Dr. Roberts is Director, High Altitude Observatory, University of Colorado.

He first spoke of the need for improving worldwide communications to spread alerts about unusual solar or cosmic activities to be observed anywhere in the world. He said this is needed because cosmic activities (sun spots or solar prominences) are of relatively short duration. Because ordinary telegraph or telephone communication appears to be too slow, a great deal of work has been done to improve methods of radio transmission. But, since solar activities interfere with radio waves, difficulties result to the extent that signals often become unintelligible.

Attempts to predict solar or cosmic activities have failed although there is hope that a great deal of statistical information being compiled may assist research workers in overcoming the problem.

The skies are full of J-M Clipper Seals

Protecting bearings in many types of aviation mechanisms

Johns-Manville's precision-moulded Clipper Oil Seals retain lubricant and exclude dirt. These seals have a dense asbestos-compound heel and a soft flexible lip concentrically moulded into one unit. This unique construction provides maximum sealability, low torque, easy installation, long life and wide adaptability. Some of their applications include:

In Actuators—In the worm gear drive of hydraulic actuators, Clipper Seals prevent oil leakage at shaft speeds of 0 to 9000 RPM, pressures of 0 to 20 psi and temperatures of –60 F to 250 F . . . with a maximum seal drag of 4 oz. Sketch shows seals used in tandem with specially developed metal adapter ring. Here, Clipper Seals replaced a far more costly seal, maintained high performance.

In Constant Speed Propellers—Used on the blade retaining nut of constant speed propellers, J-M Clipper Seals maintain a tight seal against the 400 psi pressure created by the propeller's velocity. Clipper Seals' light shaft drag permits rapid pitch changes.

Clipper Seals have also provided outstanding service in tests by major airlines in accessory drive gear trains.

In Crankshaft Assemblies
Johns-Manville developed a special split seal to permit use of an economical flange-type crankshaft in a popular engine used in small planes.

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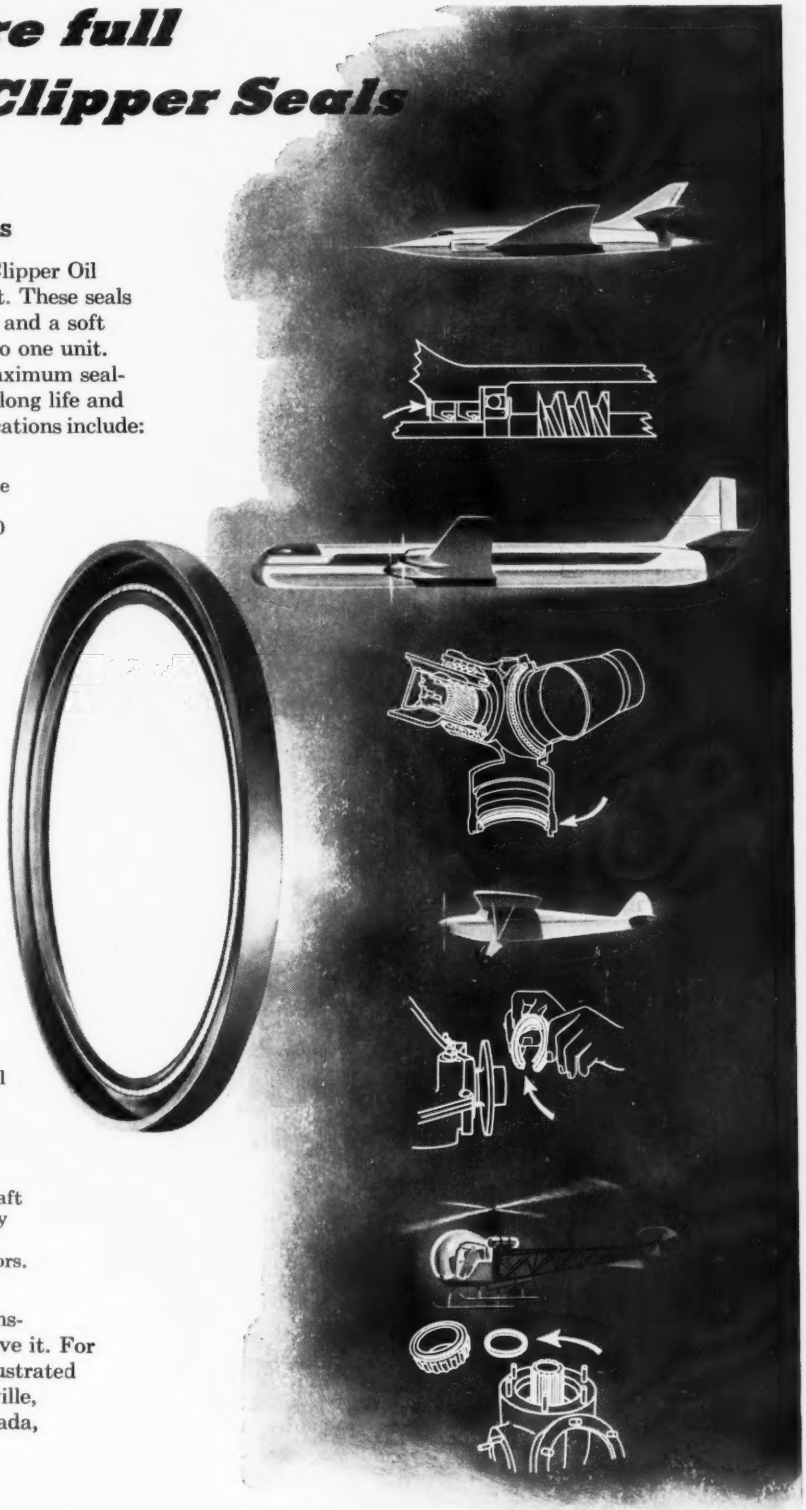

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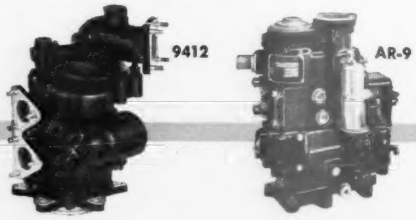

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He pointed out that the United States effort on the IGY Program will amount to nearly $100 million, involved in setting up instrumentation, obtaining basic data, processing and recording, and finally publishing the results. Two basic data centers will be set up in the United States—one at the National Bureau of Standards, University of Colorado, Boulder, Colo., and the other at Fort Belvoir, Va. Fort Belvoir will be a warning center through which worldwide alerts may be transmitted.

Groups playing an important part in the program are The Glenn L. Martin Company—to launch the satellite; the National Bureau of Standards, Radio Propagation Laboratory—to prepare special equipment to measure radiation; the University of Colorado High Altitude Observatory—one of several observation and data-recording points.

Dr. Roberts estimated that it will cost from $5 to $6 million to publish data taken from all over the world. Compilation and processing of data will necessitate use of high-speed computers, he said.

He described methods of taking data such as cosmic ray counters and photographic equipment for measuring solar prominences. Ground measurement techniques are limited because of large attenuation of all forms of radiation except cosmic rays passing through the earth's atmosphere.

The belief that high-intensity X-rays enter the upper atmosphere but never reach the earth necessitates use of a vehicle to carry instruments above the atmosphere, where accurate measurements of overall radiation can be made. The common way for doing this has been the use of sounding rockets of the Viking type. More recently "Rockoons" have been employed. This involves sending a rocket-carrying balloon up from a Navy ship. The balloon fires the rocket after reaching a high altitude.

The program first calls for launching spherical satellites without instruments to study trajectory characteristics before launching the research vehicle. The satellites will travel hundreds of miles above the earth for extended periods of time.

Such studies will yield valuable information about the upper atmosphere provided the satellites can be tracked accurately by conventional radar methods. The satellites are expected to have a 90-min. period of rotation around the earth. They will probably have instruments to measure all types of incident radiation—X-rays, cosmic rays, and electron count. Transmission to the earth will be by telemetering.

The broad objective of the program is to study cosmic effects which influence our earthly environment. One result may be long-range weather forecasting based on observations of solar activity. Another objective of the program is to promote general scientific cooperation throughout the world.

Dr. Roberts illustrated his talk with slides of the moon, the launching missile, and the satellite trajectory; cutaway view of the satellite itself, solar eruption, and sun spots; and coronagraphs made at the observatory.

A. W. GILMORE, *Secretary*

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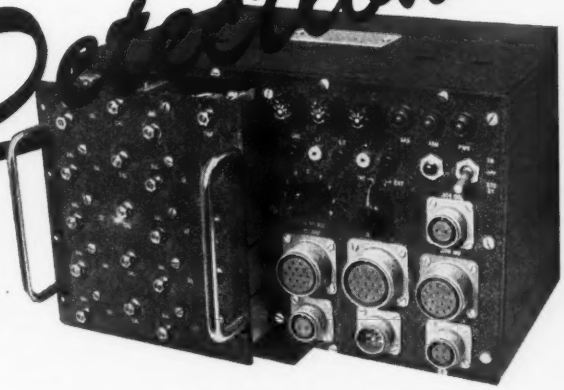

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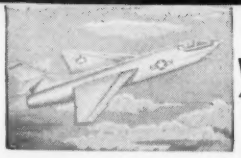

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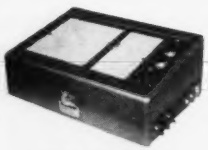

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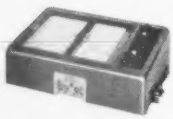

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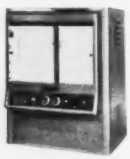

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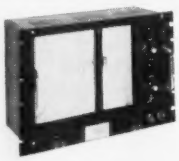

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San Antonio Section

J. J. Walden, Jr., Manager of the San Antonio office of Convair, A Division of General Dynamics Corporation, was installed as Chairman at the February 27 meeting.

Chairman Walden succeeds Col. Claude W. Smith, Commander of the 1700th Air Transport Group, Military Air Transport Service, Kelly Air Force Base. Chairman Walden, a Baylor University graduate, also is former Mayor of El Paso, Tex.

Other officers installed were Vice-Chairman H. Norman Abramson, Manager, Engineering Analysis, Southwest Research Institute; Secretary J. W. Draper, Jr., Chief, Information Services, MATS Continental Division; and Treasurer Mayor Robert A. Schneider, Office of Plans, MATS Continental Division.

After installation of officers, a report on the Section's achievements for 1956 was made. This included two major projects: encouraging youth to study engineering, aeronautical engineering in particular, and assistance to public schools in conducting an initial class on Air Transportation on the sixth grade level.

The first project featured placement of a vocational handbook, *Should I Study Engineering*, in the hands of some 4,000 high school students. These booklets were printed by Convair.

A large portion of material for the grade school course in Air Transportation was provided by members of the Section as a form of participation in the second project. The course ran for 6 weeks and will be put into the curriculum of several schools in the city.

Chairman Walden outlined an energetic program for 1957 with an opening meeting scheduled for April 17. This meeting, sponsored by the Southwest Research Institute, was to feature a program on "Aeronautical Research Activities at Southwest Research."

J. W. Draper, Jr.
Secretary

San Diego Section

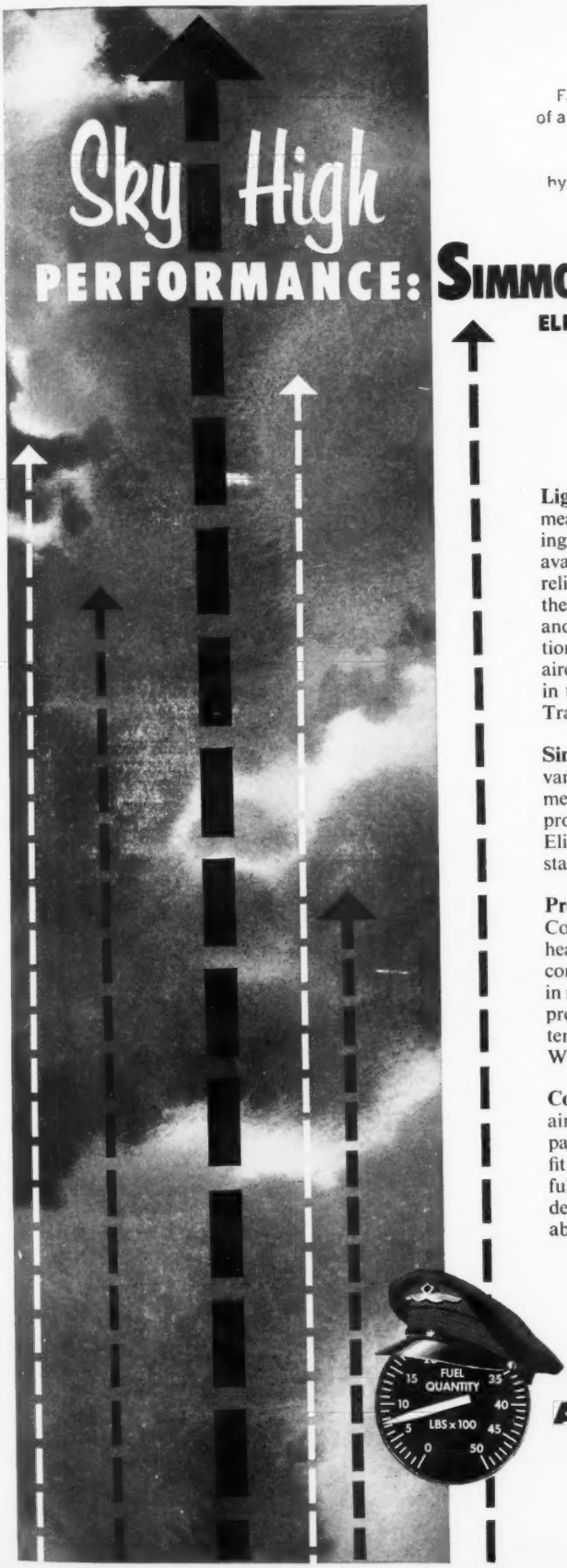
"Design Philosophy of the Convair 887 Jet Transport" was discussed by A. D. Riedler, Convair Design Specialist, at the February 7 meeting.

He outlined various criteria which must be considered in an analysis of requirements for new commercial airplanes. He explained the thinking which dictated Convair's decision to undertake design and construction of a short- to medium-range turbojet transport and gave a brief description of the 880. A question and answer period followed the talk.

▶ Gordon L. Getline delivered a paper on "Vibration and Noise in Propeller-Driven and Turbojet Aircraft" at the January 22 meeting. Mr. Getline is a Design Specialist, Convair, A Division of General Dynamics Corporation.

He pointed out that much effort is being expended in studying the characteristics of aircraft noise—its effect upon both personnel and structures and in the development of adequate methods of coping with problems.

He compared noise produced by low-



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speed, propeller-driven planes with that associated with current military and forthcoming jets. Analytical techniques and test facilities available to the noise specialist were described.

P. E. CULBERTSON
Corresponding Secretary

Seattle Section

Jay W. Miller and Jack K. Wimpress spoke on "Boundary-Layer Control and Jet Flaps" at the February 6 dinner meeting.

Mr. Miller, from Aerodynamic Preliminary Design, Boeing Airplane Company, Seattle Division, discussed boundary-layer control possibilities for improved take-off and landing performance. He listed in order of relative success the boundary-layer control measures for increasing lift and decreasing drag: geometric variations, blowing, suction, spinning parts of the surface, and electrostatic charging of the air.

He presented some basic relationships and comparisons with projected graphs and concluded that double-slotted flaps are as effective as the most feasible blown or sucked layer control systems.

Mr. Wimpress, from Aerodynamic Preliminary Design, Boeing Transport Division, said jet flaps are a means of spreading engine exhaust over an entire trailing edge and directing the sheet of air downward. He said jet flap ideas have a long history and that NACA is currently sponsoring more research. He discussed basic principles using diagrams and plots. Gains do not appear to repay the internal drags, difficult balance, and general complexity. Most awkward problems seem to be engine-out conditions, rate of climb-out, and landing cleanness.

THOMAS V. DAVIS, *Secretary*

Texas Section

Colonel Barney Oldfield, Continental Air Defense Command, spoke on "True Air Defense" before 100 members and guests at the February 26 meeting in Fort Worth.

Colonel Oldfield discussed the mission and problems of the Air Defense Command. His talk was directed primarily at the ladies because, he said, women pay attention to what other women say and so do men. He made a plea to women to understand and help the Air Defense effort by encouraging Air Force enlistments and learning to live with jet noise phenomena.

After Colonel Oldfield's talk first films of the B-58 Hustler in flight were shown by W. C. Dietz, Chief Project Engineer, Convair, Fort Worth.

A. T. CLEMEN, *Secretary*

Tulsa Section

H. W. Rudmose, Professor of Physics at Southern Methodist University, spoke on "Effects of Noise on Man" before 100 members and guests at the January 10 dinner meeting.

Dr. Rudmose discussed the recently constructed experimental loudness scale, the existence of an hysteresis effect in the human ear, attenuating effects of ear plugs and muffs, efficiency of hearing aids, ability to hear conversation over background noise, selective hearing, and the binaural effect in audio depth perception.

He gave high praise to the human ear which he called an instrument so delicate that it can respond to energy levels that move the ear drum only half the diameter of a hydrogen atom. It also is tough enough to withstand high energy levels. He marveled at the workings of the inner ear and admitted that science does not yet fully understand the process that transfers the mechanical movements of the middle ear to sound sensations in the brain.

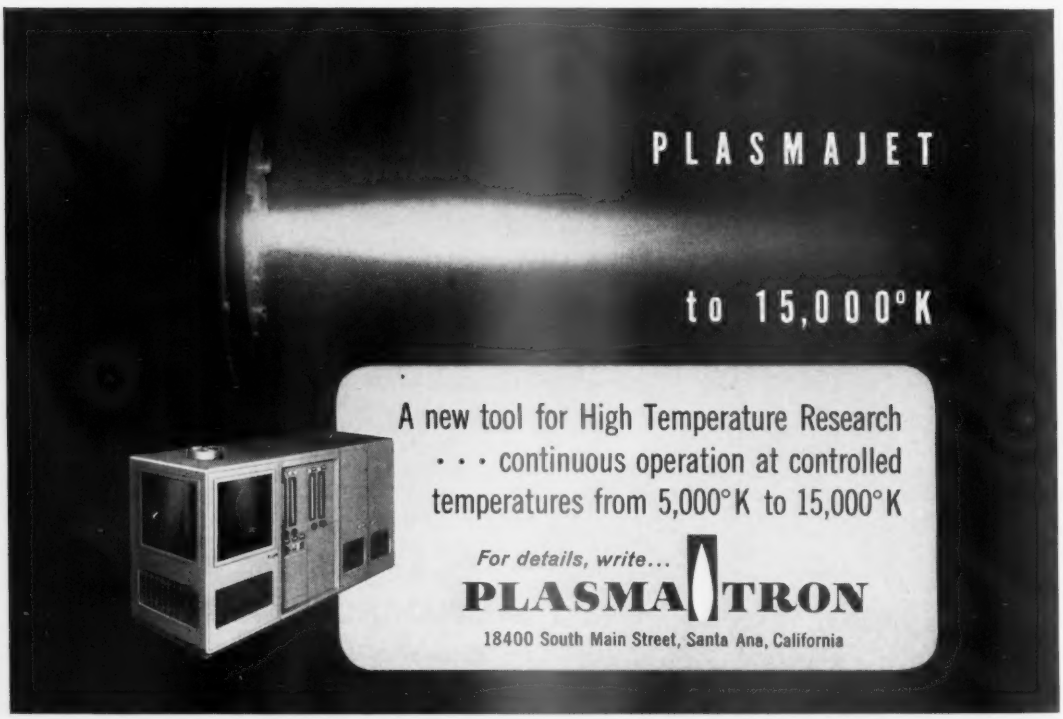
He said prolonged exposure to extremely high noise levels can permanently damage one's hearing. But, the most dangerous frequencies are not necessarily those which are most irritating (the higher audible frequencies). Also, it is not definite that in every case the ear will be damaged by the same exposure.

He said it cannot be proved that unusual or irritating noises have a deleterious effect on human efficiency other than a possible shift in the person's "threshold" of hearing.

C. K. BARTON
Recording Secretary

Washington Section

D. D. Thomas and Craig Timmerman spoke on air traffic control at the February 12 dinner meeting which was presided over by Brig. Gen. Milton W. Arnold, USAF (Ret). General Arnold, Vice-President of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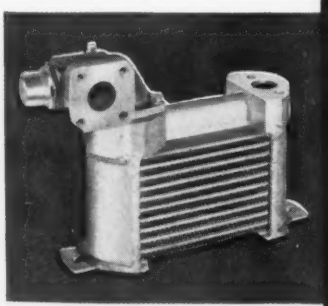

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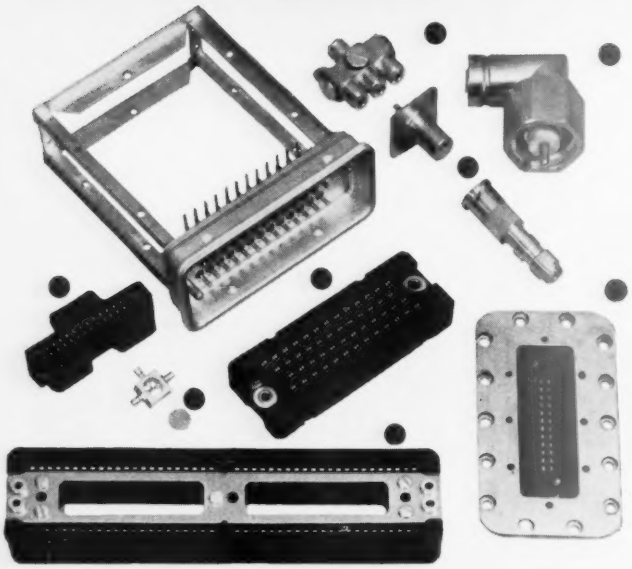

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Operations and Engineering, Air Transport Association of America, was Honorary Chairman.

Mr. Thomas, Director, CAA Office of Air Traffic Control, discussed "Current Problems of Air Traffic Control." He emphasized that it is not enough to know the longitudinal, lateral, or altitude separation of aircraft—it is also necessary to know the ability and limitations of a multiplicity of aircraft types, pilots, navigation aids, communication systems, routes, airports, meteorology, geography, and a host of related subjects.

Producing trained controllers is one of the bigger problems in meeting traffic control demands, he said. The detailed knowledge that the controller uses daily would swamp most electronic computers if all his information was stored on a memory drum.

A second problem is the display of control information. "Fix posting"—a strip of paper giving flight information from reporting points—is used despite its limitations because at present it best aids the controller in obtaining a mental picture of a traffic situation. The straight pictorial display is inadequate, and voice circuits are notoriously overcrowded and complex.

Radar has produced more spectacular results than any other single device used to date in spite of such limitations as precipitation clutter, lobing, lack of quick aircraft identification, and altitude information.

Commenting on the problem of handling jet transports, he said that experience has been gained in handling military jets for over a decade and that millions of hours of experience have been accumulated. The principal problem will be system size.

On diminishing resources of space, he said high-performance aircraft need larger cocoons of air space in which to maneuver and have protection from other aircraft. No longer is the phrase "as free as the air" applicable to aviation. In spite of these problems, Mr. Thomas said he is optimistic that continued efforts will ultimately provide the best air traffic system.

Mr. Timmerman, ATA Director of Air Navigation and Traffic Control, spoke on "Future Requirement for Air Traffic Control Systems."

He said a doubling of airlift capability is foreseeable by 1970, considering the probable growth in numbers of aircraft together with increases in performance speeds. A second factor is the trend toward more pilots' becoming capable of instrument flight with the goal of all-weather operation. With high-speed operation the "see and be seen" method of collision avoidance is obsolete for much of current operation.

Results based on these factors show that demands on the future traffic control system will increase on the order of 20 to 1 over today's system capability, in order to support many thousands of aircraft per day flying an average speed double the current speeds.

Characteristics of a future control system must satisfy four main functions:

(1) Position data, including altitude, must be made available from aircraft to controller automatically. Air-derived data through telemetering is one answer. Radar

observation from the ground is another. Both have limitations and require improvements. The second function is data correlation.

(2) The second function is data correlation. Position data now mentally calculated and written on flight progress strips by the controller should be fed by data link or radar to a computer where it will be digested, correlated, and fed to the third function—display.

(3) This function must take only significant data from the computer and display it automatically, continuously, and accurately, leaving the controllers free to make necessary control decisions.

(4) The fourth function is to provide aircraft with traffic control clearances and information through automatic transmission to a small cockpit display.

Mr. Timmerman concluded by pointing out that, except for a yet unknown technical breakthrough, meeting future demands is primarily improvement of known principles and their organization into a system concept.

G. L. DESMOND
Secretary-Treasurer

Wichita Section

A comprehensive picture of Wichita University School of Engineering was given by the school's dean and two faculty members before 34 members and guests at the February 6 meeting. The speakers were Dean Kenneth Razak; Melvin Snyder, Head of the Aeronautical Engineering Department; and Bob Wattson, Chief Engineer of the Research Department.

Dean Razak presented a brief history of the school from its beginning in 1943 to its first graduating class in 1948. Current enrollment is 1,350 students, he said. About one third work either full time or part time. Curricula lead to B.S. degrees in Aeronautical, Civil, Industrial, Mechanical, and Electrical Engineering. Advanced courses available lead to an M.S. in Aeronautical Engineering. Engineering combined with liberal arts may provide a B.A. degree in one of the above subjects.

He said close contact between the school and local industry keeps material offered up to date and furnishes the student with a first-hand example of the application of his knowledge.

Professor Snyder reviewed activities of his department, pointing out that the School of Engineering was the first in the country where a degree in Aeronautical Engineering was the first degree given in engineering. He said there are about 310 undergraduates studying Aeronautical Engineering, 17 of whom will graduate this spring. The night school is gaining momentum despite the fact it takes 9 years to obtain a degree by this means alone.

The main problem facing many engineering schools today is that of freshmen who are not prepared to begin a curriculum leading to an engineering degree. A lack of mathematical training is the cause. He suggested that engineers be prepared to accept the responsibility of consulting high school students at every opportunity afforded to alleviate the problem.

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Mr. Wattson pointed out aspects of work accomplished in his department and plans for future programs and facilities. He said research activities have been generally centered about the 7 × 10 Walter Beech Memorial wind tunnel, problems of boundary-layer control, STOL, and other smaller projects of private industry. He said it is essential to provide the atmosphere conducive to the generation of ideas at the working level in research work. He showed a color movie of the tunnel in operation.

Dean Razak concluded with what he thought was the prime problem in engineering education—the shortage of qualified persons interested in teaching at the graduate level. The size and curricula of any graduate school are limited by the available teaching staff he said.

After the discussion, members visited the school's Research Department.

EDWARD J. SULLIVAN, *Secretary*

STUDENT BRANCHES

Academy of Aeronautics

A semiannual dance, given jointly by the Branch and its SAE counterpart, was held November 31.

▶ Lewis Knapp lectured on "Preliminary Design of the Helicopter" at the November 20 meeting. Mr. Knapp is Senior Preliminary Design Engineer at United Aircraft Corporation, Sikorsky Aircraft Division.

He discussed the basic method of attacking a preliminary design problem. Compromises in such design parameters as rotor solidity, tip speed, and disc loading that are necessary to obtain a practical design were pointed out. A discussion period was held after the talk.

▶ More than 60 new members attended the October 24 meeting and were briefed on the by-laws and purpose of the Branch.

DAVID C. CLYMER
Corresponding Secretary

Alabama Polytechnic Institute

Vaughn L. Beals lectured on "Flutter and Vibration Problems in the Design of High-Speed Military Aircraft" at the February 19 meeting. Mr. Beals is Group Leader, Flutter and Vibration, North American Aviation, Inc.

He traced a flutter problem from the experimental program through the theoretical program when final analysis is made after flight test. He illustrated this with slides.

Two films shown at the meeting were *Small-Scale Flutter Test* and *The Application of Rocket Sled Techniques to Flutter Testing.*

▶ S. Walter Hixon spoke on "Research at the National Advisory Committee for Aeronautics" at the February 12 meeting. He is an NACA Training Officer.

Some 35 students heard him describe research problems and wind tunnels at Langley Air Force Base.

▶ "The Chance Vought Low-Speed Wind Tunnel" was discussed by Harold A. Bagnell at the February 5 meeting. Mr. Bagnell is Supervisor of the tunnel.

He told 68 members present how the tunnel was developed and described its operation.

GERALD M. MOSELEY
Secretary

Boston University

Twenty new members were accepted at the February 18 meeting which opened with a discussion of Branch activities by Chairman Frank Cardone.

Faculty Adviser Leonard Waxer spoke on aspects and advantages of Institute membership after graduation. He said the IAS can render excellent technical assistance through its publications and library services.

Lawrence Cianciolo was elected Vice-Chairman, and Ralph D'Amelio, a new member, was elected to the Activities Committee.

FRANK H. NICHOLS, *Secretary*

The Catholic University of America

Paul E. Gerber, Curator of the National Air Museum of the Smithsonian Institution, spoke on "The Wright Brothers" at the February 28 meeting.

Mr. Gerber highlighted his talk with a collection of original photographic slides depicting the first attempts to fly by the Wright Brothers. The slides illustrated the slow progress in developing their first aircraft.

Mr. Gerber also discussed plans for expansion of the Air Museum facilities. Purpose of the plans is to recognize, preserve, and display the history of American aviation.

▶ James Mulquin, a member of the Branch, spoke on "The Tactical and Operational Role of the Aircraft Carrier" at the January 10 meeting.

Mr. Malquin drew from his experiences serving on carriers in the Navy. After his talk a film, *Fifty Years of Powered Flight*, was shown.

During the business meeting plans for attending the Regional Student Conference at the University of Virginia were discussed. A delegation of six members and Faculty Adviser Gabriel Boehler are scheduled to attend the conference. Two seniors will present papers.

PATRICK J. FERRITER
Chairman

Iowa State College

A new slate of Branch officers was installed at the February 27 meeting. They are Larry Smith, Chairman and Senior Representative on the Engineering Council; LaVerne Seversike, Vice-Chairman; Kendall Wicks, Treasurer; John E. Anderson, Secretary; Jerry Walter, Program Chairman; and Dick Gallagher, Junior Representative, Engineering Council.

E. W. Anderson, Head, Aeronautical Engineering Department, continues as Faculty Adviser.

▶ "Research Problems of Supersonic and Hypersonic Flight" were explained by George Edwards at the February 19 meeting. Mr. Edwards is a member of NACA's Ames Aeronautical Laboratory, Moffett Field, Calif.

He discussed stability and control, aerodynamic interference, piloting high-speed planes, and aerodynamic heating. He also showed slides of Moffett Field facilities.

▶ P. W. Rowe discussed "Aerodynamic Heating" at the February 6 meeting. Mr. Rowe is associated with the Sandia Corporation, Albuquerque, N.M.

He explained fundamental principles of heating and enlarged on problems of high-speed flight. His talk was illustrated with slides of Sandia facilities.

MARVIN BAXENDALE, *Secretary*

Louisiana State University

New officers elected during the February meeting for the spring semester were Kenneth Morrison, Chairman; Rene R. Rivers, Vice-Chairman; Douglas D. Duhon, Secretary; and George E. Muller, Jr., Treasurer.

After the election, participation in the Engineering Day program was discussed. Committee chairmen reported on progress of the Branch in the program. Hope was voiced that the Branch would gain more members through the program.

DOUGLAS D. DUHON, *Secretary*

New York University

Plans for the spring semester were outlined and a scope of activities scheduled at the February 6 meeting.

Activities will include an engineering demonstration day for visiting high school seniors (the Branch will conduct the demonstration in the aeronautical department); a field trip to Republic Aviation Corporation facilities; and a guest speaker, Lt. Paul Lieberman, past Secretary of the Branch and N.Y.U. alumnus stationed at the Rocket Engine Test Laboratory at Edwards AFB, Calif.

A film shown at the close of the meeting was titled *Some Results of the Princeton University Smoke Flow Visualization Program.* The film, made in conjunction with the Air Branch, Office of Naval Research, illustrated basic flow patterns caused by bluff and streamlined shapes under varying conditions.

▶ Meetings on February 18 and 25 were devoted to discussion and two films—*The Jet Story* from General Electric Company and a movie on facilities at Convair, A Division of General Dynamics Corporation.

MARVIN D. BARKAN, *Secretary*

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North Carolina State College

John D. Louthan, Aerodynamics Project Engineer at Chance Vought Aircraft Incorporated, spoke on "Weight and Performance Considerations in the Design of High-Speed Aircraft" at the February 12 meeting.

Mr. Louthan explained some of the problems met in the preliminary design of high-speed aircraft and later showed a film, *Operation One Grand*. The film depicted the F8U Crusader winning the Thompson Trophy.

There was a brief discussion period after the movie during which Mr. Louthan answered questions.

JESSE W. HARRELL
Corresponding Secretary

Oklahoma University

The February meeting of the Branch featured three speakers from the General Electric Company's Midwest City facility who discussed problems associated with designing, producing, delivering, and servicing aircraft engines.

The speakers, led by S. K. Middleton, covered three major fields: overhaul and maintenance, operation and tests of electronic and hydraulic controls, and air driven pumps. The trio pointed out that an engine must be designed so that certain repairs can be made on the flight line through access portals. An engine designed for ease of maintenance and overhaul can save the Government much time and money.

Keeping the controls simple enough so that a pilot can accomplish his many duties is a big problem. The speakers explained the problem of compromising the controls between reliability of the hydraulic system and the ability of electronic instruments to handle more complex controls.

Various pumps necessary in an aircraft, how they are driven, and problems that arise in designing pump turbines were discussed.

The last part of the meeting was devoted to a discussion of Branch participation in the university's Engineering Open-House program.

JAMES R. BRACE, *Secretary*

Oregon State College

Nine members of the Branch accompanied by H. D. Christensen, Faculty Adviser, visited Boeing Airplane Company's Seattle facilities on January 24.

Boeing personnel gave informal talks on various projects. Development of the firm's gas turbine was discussed in comparison to other turbines. Robert E. Davison of the Hydraulics and Controls Group introduced members to nonclassified information on the Bomarc project. The project has been in progress since 1951. B. F. Ruffner, a former Professor at Oregon State, spoke of Boeing as a future employer.

The group visited the new supersonic wind tunnel under construction and other testing facilities. The blow-down type of tunnel will have a supersonic range up to Mach 4. The transonic tunnel, altitude testing equipment, heat box, refrigeration testing units, and some structural tests were seen.

Donald W. Finlay, an Oregon State graduate and Project Engineer for the 707, discussed the history of Boeing from its first aircraft to the latest modern transport. Facilities at Renton where the 707 and KC-135 are being built were visited. The 707 is designed to have a pay load exceeding anything in commercial aviation to date. The KC-135 assembly line and some of the testing work on the 707 were seen. An interesting feature of the visit was seeing the mock-up section.

WILLIAM K. HOWELL, *Secretary*

Polytechnic Institute of Brooklyn

Two representatives from the Naval Air Development Center outlined operations research and described opportunities for the engineering graduate in their department at the March 5 meeting.

Transportation arrangements were completed for the Branch's field trip to Grumman Aircraft Engineering Corporation.

▶ Jerome Persh, Assistant Chief of the Naval Ordnance Laboratory, Aeroballistics Research Department, spoke on the laboratory's facilities and activities at the February 26 meeting.

The department is divided into four groups: applied mathematics for operation of electronic computers, aerodynamics for developmental and test work, hyperballistics for experimental and theoretical range work in high-speed aerodynamics and studies in real gas effects, and aerophysics for heat-transfer and boundary-layer research.

Lab facilities include two 16-in. test section tunnels with ranges of Mach 1 to 5. A blow-down type of tunnel is used to study aerodynamic effects. A continuous tunnel is used for heat-transfer and boundary-layer research. The lab also operates a 12 × 12 cm. blow-down tunnel and has plans for building a 20-in. tunnel for Mach 5 to 10 range. The new tunnel will have a maximum running time of about 4 hours.

The lab also has a number of tubes in which ballistic models are fired from explosive charge guns and observed in motion by high-speed cameras. Plans call for new light gas guns for model firing and miniature telemetering equipment inside models.

▶ Plans for the annual banquet of the Branch, to be held in April or May, were discussed at the February 19 meeting.

▶ Two films, *Accessories for Milady* and *T2V-1 Jet Trainer*, were shown at the February 13 meeting. The first film depicted increasing importance of engine and flight control accessories for successful completion of civil and military missions.

The second film showed the evolution of the Navy's latest trainer beginning with the F-80 air frame. Changes in aerodynamic, structural, and propulsion components to meet needed performance, strength, and control requirements for carrier training were covered.

▶ James L. Cooley, Supervisor of the Aircraft Performance Group for United Aircraft Corporation's Research Department, spoke on "The Design and Evaluation of an M-2 Aircraft" at the January 16 meeting.

He said designers in the aircraft engine and accessory field need to know future trends in air-frame design so they may better plan their own products. He outlined typical procedures followed by his group in the study of a supersonic fighter configuration.

A probable high-speed, high-altitude combat mission is taken as a starting point. After the mission profile is plotted, an estimate is made of the maximum required engine thrust. For a particular engine size, a minimum fuselage is necessary to enclose the pilot, electronic equipment, landing gear, fuel, and other components. This is how the general size of the aircraft is established.

Using available aerodynamic propulsion and weight data, basic relationships are varied one by one and then compared to known designs in order to optimize the necessary design parameters and so obtain the best possible design for the required mission. The final configuration provides trend data years ahead of current aircraft for advanced designers in the airframe supporting industries.

▶ An amendment to the Branch by-laws dealing with the use of money appropriated for an annual banquet was approved at the January 9 meeting. It was proposed that the banquet be attended by active seniors of the Branch.

A film on the Matador missile also was shown. Pictures of its zero-length launcher, delivery of the first test missile to Patrick AFB, and a typical missile firing and tracking sequence were shown.

▶ Two films, *History of the Helicopter* and *Harnessed Lightning*, were presented at the January 2 meeting.

The first film described the helicopter as having added a new dimension to flight. Development was shown beginning with nature's helicopter—the hummingbird—through da Vinci's early sketches and first experiments with models. According to the film, many years were required to develop light powerful engines, but even then the early models were unstable.

After a brief review of contemporary craft, glimpses of the helicopter's military and commercial utility were given.

The second film outlined the development of jet propulsion. The industry's background in reciprocating-engine design and production, a cutaway of a typical turbojet engine, and a panorama of present and proposed aircraft using these power plants were depicted.

ALLEN J. SCHNEIDER
Recording Secretary

Princeton University

Some 50 members and guests heard three engineers from The Glenn L. Martin Company discuss Project Vanguard at the February 12 meeting.

A brief history of the project and three main problems involved were described. The problems were to establish the 21-in. sphere in a prescribed orbit, to prove the satellite is actually in orbit, and to obtain useful information from it.

The first problem is the responsibility of Martin and comprised the remainder of the talk. The three stages of the vehicle and their propulsion systems were explained with slides.

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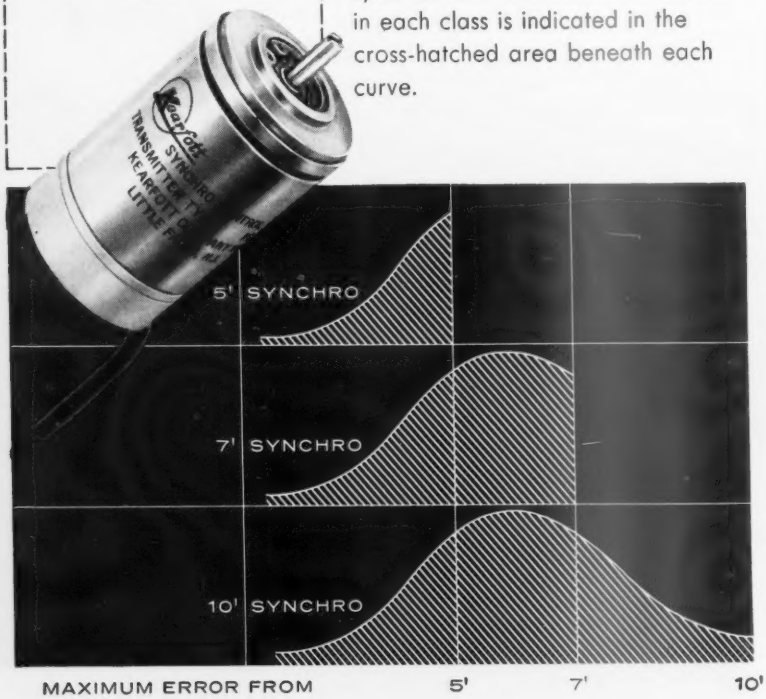

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After the talk and a question and answer period, a film of the Viking rocket was shown. The film depicted the rocket breaking away from its moorings during a tie-down test.

JACK E. SNELL, *Secretary*

Rensselaer Polytechnic Institute

Branson Smith spoke on factors which affect design of propulsion systems for high-speed aircraft and future aircraft at the February 13 meeting. Professor Smith is on the faculty of the Hartford Graduate Center and is associated with United Aircraft Corporation's Pratt & Whitney Aircraft Division.

Some of the propulsion systems discussed were the turbojet, turboprop, ramjet, ducted fan, and rocket engine. Velocity ranges for these engines also were explained.

Professor Smith pointed out the importance of forecasting future needs when designing an engine. This is to make sure a suitable engine will result on the production line after the necessary 10 to 15 years in research and development are completed. A firm also must take into account its manufacturing potential.

Once specifications for an engine are evolved, the design stage begins, he said. Thermal, structural, and aerodynamic effects must be considered in the design. The most critical problem is the lack of adequate heat-resistant materials.

The meeting was closed after a question and answer period.

ROBERT E. KELLY
Secretary-Treasurer

San Diego State College

The Branch participated in an Engineer's Week program by attending a combined meeting of all campus engineering societies February 19. A panel discussion on "What Can a Beginning Engineer Expect on His First Job?" was held.

The panel was composed of three students and three engineers from industry and Government. Students were Hans Dahlke, Larry Lynes, and Orville Elzie. Engineers were F. Jorgenson, California State Division of Highways; L. Miller, Power Plants, Convair Division of General Dynamics Corporation; and Captain McDonnell, USN, Public Works.

Questions asked centered on the advisability of graduate work for engineers, what today's engineering graduates are lacking, and the shortage of engineers.

JAMES R. FRAHM, *Secretary*

Tri-State College

New officers elected for the spring semester at the February 28 meeting are Norman J. Wellott, Chairman; Phillip E. Emanuel, Vice-Chairman; Kazumi Hamada, Secretary; Richard Auyer, Treasurer; and Rodney P. Cravens, Reporter.

The meeting was highlighted by a lecture on "Engineering Practices and Products of Beech Aircraft Corporation" given by Herb Rawdon of the firm's

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Commercial Airplane Department. He is a graduate of Tri-State, Class of 1925.

Mr. Rawdon illustrated his talk with slides.

▶ Nominations for officers for the spring quarter were received at the February 14 meeting. Voting was scheduled for February 21.

Plans for the spring quarter call for films to be shown at each meeting. The Branch also is canvassing for speakers and is investigating Martin and McDonnell aircraft companies for a possible field trip.

A film called *Harnessed Lightning* was shown at the close of the meeting.

EUGENE O. PRUE, *Secretary*

University of Illinois

Ted Dansby, Aerodynamicist for Convair, A Division of General Dynamics Corporation, spoke on "Selecting a Plan Form for a High-Speed Bomber" at the February 14 meeting.

He showed a sequence of slides on various problems encountered in the selection of a correct plan form. He emphasized parameters and areas in which compromise in certain characteristics must be made.

A film of the B-58 Hustler during ground tests and its first flight test was shown.

During the business meeting Open House Chairman John Kistenbroker gave a report on the Engineering Open House program. Membership fees for the semester were collected, and membership cards were filled out.

▶ Officers for the spring semester were introduced by Chairman Donald Glennie at the last meeting of the fall semester. They are J. T. Martin, Vice-Chairman; J. S. Harper, Secretary; C. A. Darling, Treasurer; and A. C. Culver, Engineering Council Representative.

Films to be shown at a later meeting are *The History of the Helicopter* and *The Flying Wing*.

JERRY L. HARPER, *Secretary*

University of Kentucky

Latest Air Force developments were depicted in a movie lent to the Branch by the AFROTC for its February 14 meeting.

After the film, ideas for promoting interest in the Branch were discussed. Participation in the university's Engineer's Day, May 10, was suggested.

ALBIN L. WITTWER, *Secretary*

University of Maryland

Paul A. Thurston, a member of the Aeroballistics Section, Naval Ordnance Laboratory, spoke on "Shock Waves" before 19 members and guests at the February 21 meeting.

He discussed the nature of normal shock waves and developed the Rankine-Hugoniot relationships. He showed a demonstration shock tube and slides to illustrate his talk.

A letter was received from engineering students in Greece who want to exchange letters with students at Maryland.

GAIL D. WISSER, *Secretary*

University of Michigan

Vaughn L. Beals, Group Leader, Flutter and Vibration Section, North American Aviation, Inc., spoke on "The Application of Rocket Sled Techniques to Flutter Testing" on February 12.

Mr. Beals outlined the background of flutter and noted that only since 1952 has flutter become a major design problem. This is because of the high speed of modern aircraft. He said the rocket sled is the sole means for the flutter engineer to study and test flutter in full-scale structures. The sled allows flutter to destroy the structure without danger to human life. Sled tests take place before flight tests to determine critical flutter speeds.

Two general types of sled are used—special purpose and platform. The special-purpose sled is designed solely for a specific test. The platform sled is a general-purpose vehicle on which a wide assortment of test items may be mounted with minor changes in the sled. Either type weighs from 3 to 5 tons. Mr. Beals said two factors which must be minimized in sled design are form drag and the choking effect of the air rammed at high speeds between the track and the bottom of the sled.

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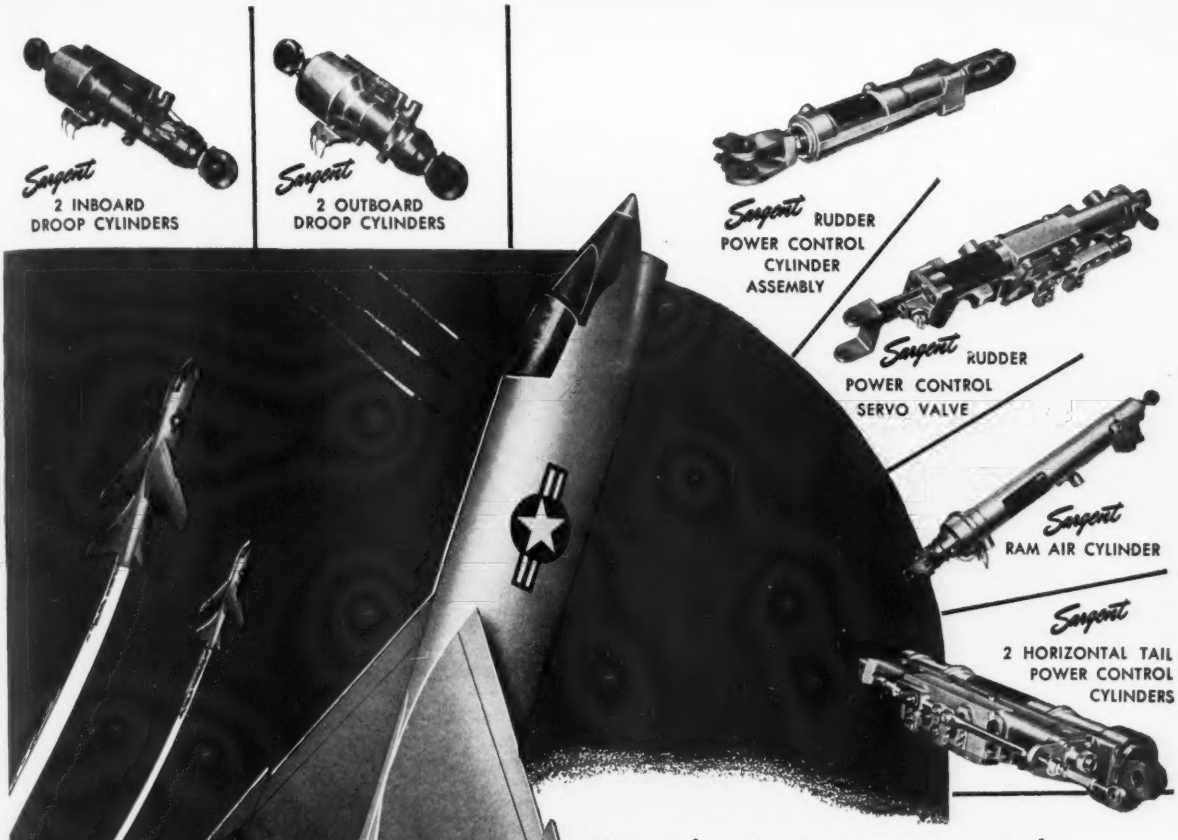

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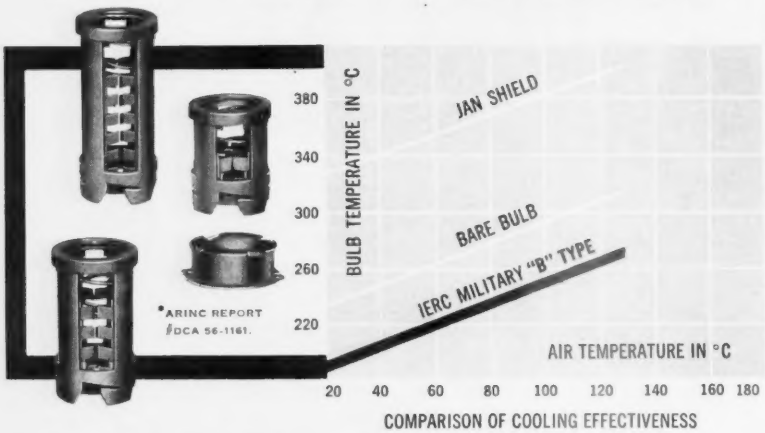

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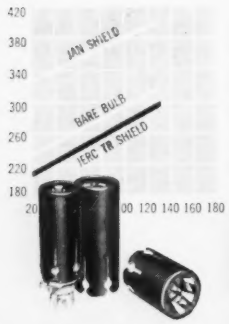

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speed desired. Once the desired speed is reached, smaller rockets are used to maintain a 1g acceleration so that velocity will increase slowly until critical flutter speed is reached.

The greater length of the track is used to brake the sled. This is done in two stages: allowing the sled to coast to let drag and track friction reduce speed, and use of an outrigger device dragged in a gradually increasing depth of water in a trough located beneath the sled between the tracks. This is the method used at the longest track at China Lake, Calif. (4.1 miles long). Another means of braking is use of reverse rockets on the sled.

Sled-test data come from such sources as sled-mounted accelerometers, strain gages, and cameras. Best information on flutter testing comes from high-speed cameras mounted on the sled.

Mr. Beals showed a film on flutter testing on empennage components of the FJ-4 Fury.

▶ New officers introduced at the January 8 meeting were John P. Wenzelberger, Chairman; Joseph T. Liu, Vice-Chairman; Michael A. Reynolds, Secretary; and Roger L. Severson, Treasurer.

After the introduction, Don Ahrens of Cessna Aircraft Company spoke on "Problems in Designing the Light Plane." He covered the economics involved and the problem of satisfying the whims of customers. Seven new members were among 58 members and guests who heard the talk.

MICHAEL A. REYNOLDS, *Secretary*

University of Texas

Harold T. Johnson, Convair Division, General Dynamics Corporation, discussed the B-58 Hustler before some 200 members at the March 1 meeting.

Highlight of his program was a film, *The First Flight of the B-58*, which showed close-up shots in static, taxi, and flight tests. The film was in color.

Mr. Johnson said development of a modern plane consumes a time span measured in years rather than months. For example, the B-36 was first conceived in 1941 but did not reach the production stage until 5 years later. This is the average development time. He also gave a brief outline of the plane's characteristics.

Tires used on this plane have an almost rectangular cross section to increase braking power. Wheels had to be designed necessarily small to retract completely into the wells of the thin delta wings.

After the movie the audience engaged Mr. Johnson in a question and answer session.

▶ More than 100 members and guests heard J. W. Ludwig describe the Chance Vought Crusader at the February 18 meeting.

He outlined procedures used to time the fighter in its preparation for the Thompson Trophy Race. Most timing equipment was electronic, he said, but one method involved the use of a stop watch. He also described some of the fighter's characteristics which enabled it to win the race.

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After his talk, Mr. Ludwig showed a film *Operation One Grand* which illustrated the Crusader in flight. A question and answer period followed the film.

Officers elected at the February 11 meeting for the spring semester were Dave Moore, Chairman; Paul Greer, Vice-Chairman; Ken Koether, Treasurer; Scott Jackson, Recording Secretary; Robert Corter, Corresponding Secretary; and Mike Sarabia, Engineering Council Representative. Faculty Sponsor for the semester is William H. Shutts.

Professor Shutts explained IAS organization to the 75 students present. M. J. Thompson, Chairman of the Aeronautical Engineering Department, commented on scholarships available to outstanding aeronautics students.

Short talks on future Branch activities were given by Robert Battey, who spoke on the Power Show, and Robert Courter, who outlined requirements for the Student Paper Competition.

ROBERT W. COURTER
Corresponding Secretary

University of Wichita

Cliff Johnson was elected Vice-Chairman at the February 15 meeting to fill the vacancy created by Frank Macheers who was graduated in January.

Members discussed the St. Louis and Texas Student Paper Competitions. Verne Hoehne, whose paper was judged best in the Branch, was offered a choice of entering either competition. Other members who will submit papers are Jim Bede, Jack Wolf, and Earl White.

The supersonic nozzle which the Branch is building for display at the Engineering Open House has been completed, Committee Chairman Don Palmer reported.

Two films, *X Minus Zero* and *Airpower*, were shown after the business meeting.

WARREN CHICHESTER, *Secretary*

Wayne State University

New officers of the Branch were introduced at the February 8 meeting. They are Frank Ottati, Chairman; Edward Coleman, Vice-Chairman; Max D. Russell, Secretary; and Willliam Glunt, Treasurer.

Mr. Coleman announced that a trip to North American Aviation facilities and Ohio State University has been tentatively scheduled for the Easter holiday, April 25-27.

Mr. Ottati urged members to submit technical papers for the annual Regional Student Paper Contest scheduled for May 7.

The following films from the Giannini Film Library were shown: *The Kaman Turbo-Rotor Helicopter*, *Jet Power*, and *The Intruder*.

MAX D. RUSSELL, *Secretary*

MEMBERS ELECTED

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the Review.

Elected to Associate Fellow Grade

Higgins, Harry C., B.S. in M.E., Chief, Aerodynamics, Boeing Airplane Co. (Wichita).

Multhopp, Hans, Principal Scientist, The Glenn L. Martin Co.

Transferred to Associate Fellow Grade

Arkin, Shepard M., M.S. in Ae.E., Staff Engr., Missile Systems Div., Raytheon Manufacturing Co.

Haddon, Mathew C., B.S. in Ae.E., Chief Engr., Lockheed Aircraft Corp. (Burbank).

Haney, William R., Jr., M.S. in Ae.E., Field Engr., Wm. R. Whittaker Co., Ltd.

Parker, Jack S., B.S. in M.E. V-P and Gen. Mgr., AGT Div., General Electric Co. (Cincinnati).

Pierpont, P. Kenneth, M.S. in Ae.E., Aero. Research Engr., NACA (Langley Field).

Schuld, Emil P., M.S. in Ae.E., Comdr., USN; Exec., AGARD (Paris).

Wrigley, Walter, Sc.D. in Appl. Physics, Prof. of Aero. Engrg., Massachusetts Institute of Technology.

Elected to MEMBER Grade

Adams, Richard M., B.S., Sr. Engr. X, Special Products Div., American Motors Corp.

AuWerter, Jay P., M.S., Pres., Atlantic Automatic Co.

Benjamin, Roland J., Ph.D. in Appl. Mech., Sr. Aero Engr., Cook Research Labs.

Bernstein, Abe, B. of M.E., Group Engr., Philco Corp.

Bolton, Robert H., B. of E.E., Sr. Engr., Sperry Gyroscope Co.

Born, Richard E., B.S. in M.E., Sales Engr., Westinghouse Electric Co. (Los Angeles).

Briggs, William B., M.S. in M.E., Supvr., Theoretical Propulsion, Chance Vought Aircraft, Inc.

Burn, Edward R., B.S. in Ae.E., Asst. Proj. Engr., Lockheed Aircraft Corp. (Marietta).

Cervenka, Adolph J., B.S. in M.E., Supvr., Combustion Systems Design, Turbomotor Div., Curtiss-Wright Corp.

Dietrich, Henry T., M.S., Asst. to Pres., Kaman Aircraft Corp.

Duffy, Paul E., B.S. in C.E., Tech Engr., General Electric Co. (Cincinnati).

Ehlers, F. Edward, Ph.D., Research Specialist, Mathematical Services Unit, Boeing Airplane Co.

Epps, Max, M.S. in Ch.E., Fuels Consultant, General Petroleum Corp.

Etemad, Galen A., Ph.D. in M.E., Research Specialist, Engrg., North American Aviation, Inc. (Los Angeles).

Faye-Petersen, Rolf, M.S. in Ae.E., Research Engr. "B," Boeing Airplane Co. (Wichita).

Garber, Albert M., M.S. in M.E., Engr., Thermal Stress & Creep, General Electric Co. (Philadelphia).

Gerrard, John H., Ph.D., Lecturer, Mechanics of Fluids, Manchester Univ.

Hawk, Jerre T., B. of M.E., Design Engr., Douglas Aircraft Co., Inc. (Santa Monica).

Johnson, James H., Jr., M.S. in Appl. Mech., Supvr., Struct. Analysis Methods, North American Aviation, Inc. (Downey).

Lermer, August S., Dipl. Ing., Sr. Dynamics Engr., Convair Div. (San Diego), General Dynamics Corp.

Looman, Fey K., B.S. in I.M.E., Design Engr., Douglas Aircraft Co., Inc. (Long Beach).

Lorenc, Stanley A., Dipl. Ing., Analytical Engr., Turbomotor Div., Curtiss-Wright Corp.

Mack, Henry J., B.M.E., Sect. Head, Curtiss-Wright Corp.

Marvin, Richard H., M.S. in M.E., Asst. Dir., Airframe Research Div., The Budd Co.

Medlin, William W., Chief Proj. Engr., Holmes & Narver, Inc.

Myklebust, I. Leonard, Jr., B. of C.E., Engr., Hughes Aircraft Co.

Norton, Frank R., M.A. in Physics, Tech. Dir., Electronic Instrumentation Div., The Ramo-Wooldridge Corp. (Denver).

Peters, Frank W., B.S. in Ae.E., Dynamics Engr., Radioplane Co.

Pflieger, Waylon D., B.A., Struct. Engr., Ryan Aeronautical Co.

Pfyl, Frank A., M.S., Group Leader & Proj. Engr., Ames Aeronautical Lab., NACA (Moffett Field).

Polak, Irving P., B.S. in M.E., Proj. Engr., Marquardt Aircraft Co.

Reinhold, Richard S., B.S. in C.E., Chief, Struct. Devel., Boeing Airplane Co.

Richter, James H., B.S. in Ae.E., Aerodynamicist, Grumman Aircraft Engineering Corp.

Scarborough, Robert W., B.S. in M.E., Chief, Propulsion Staff, The Glenn L. Martin Co.

Schum, Eugene F., M.S. in M.E., Research Engr., North American Aviation, Inc. (Columbus).

Shapiro, Stanley R., B.S. in M.E., Supvr., Performance Analysis, Turbomotor Div., Curtiss-Wright Corp.

Silber, Edward H., Aircraft Engine Specialist, General Electric Co. (Los Angeles).

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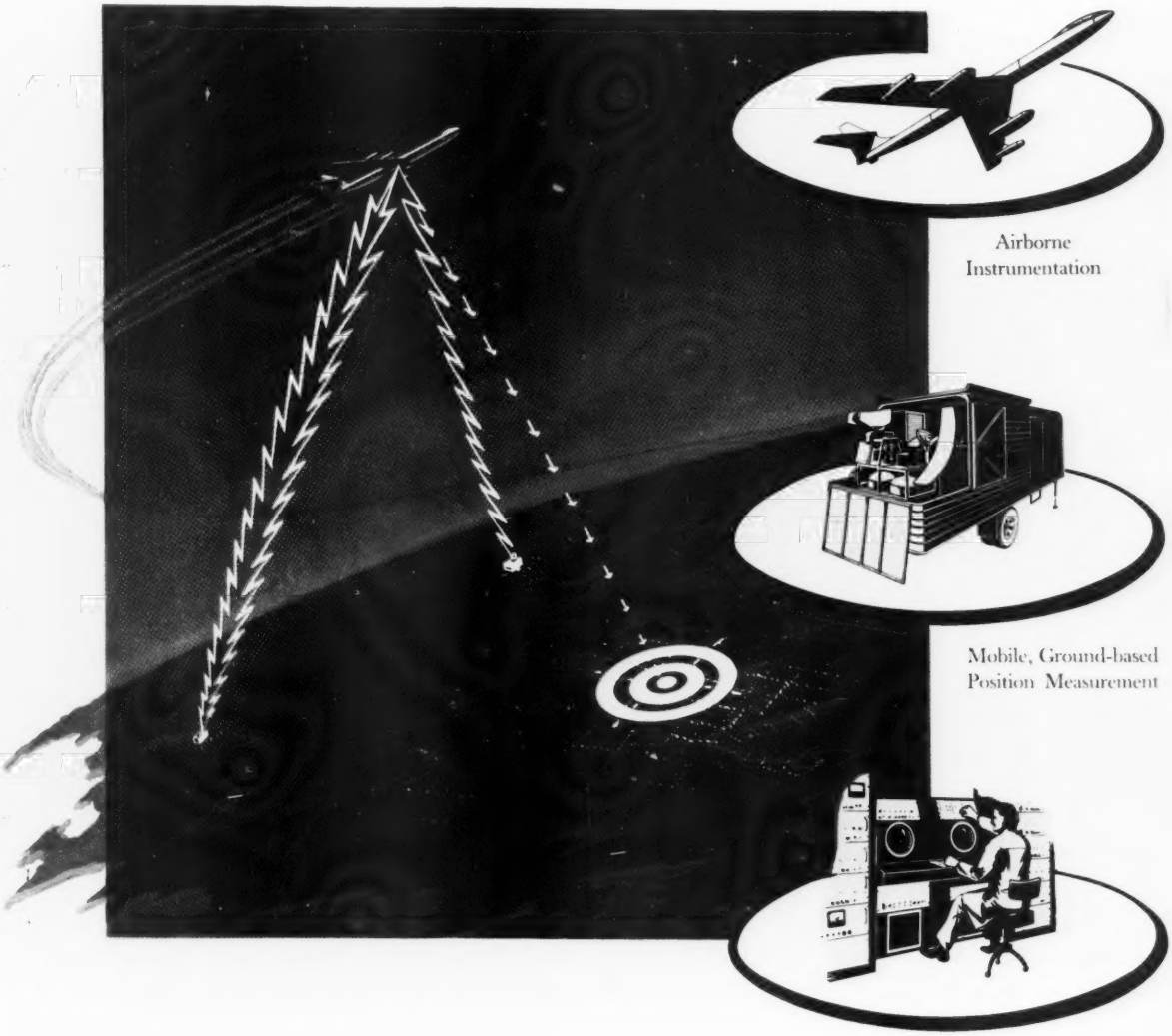

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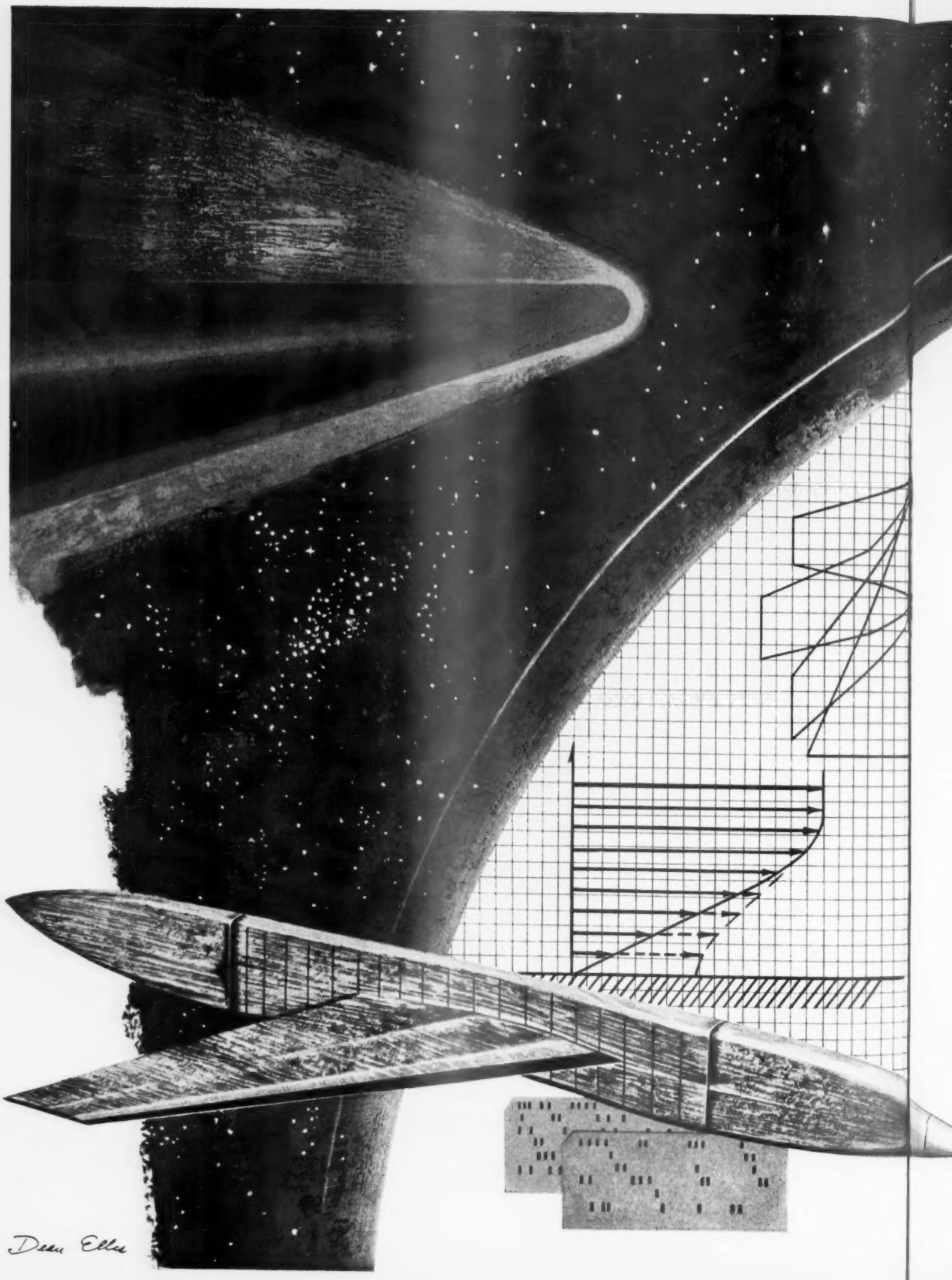
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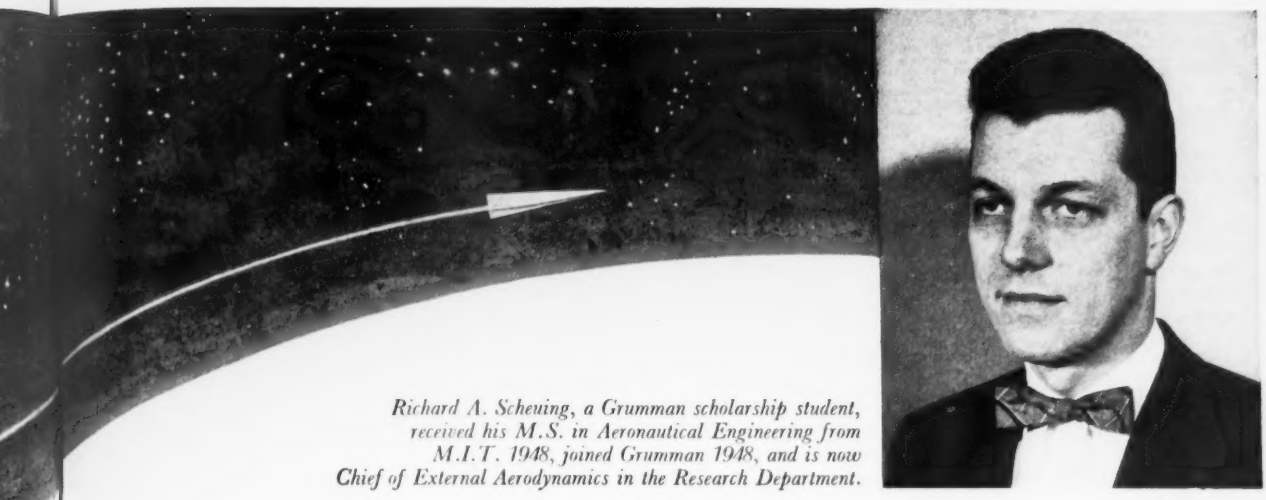

Richard A. Scheuing, a Grumman scholarship student, received his M.S. in Aeronautical Engineering from M.I.T. 1948, joined Grumman 1948, and is now Chief of External Aerodynamics in the Research Department.

AERODYNAMIC RESEARCH

by RICHARD A. SCHEUING

At Grumman a considerable amount of work is being carried out on many phases of aerodynamic research. Much effort has been devoted to the analysis of wing-body interaction effects at supersonic speeds; and a method of determining fuselage contours for maximum zero-lift wave drag reduction has been derived and extended to the lifting case. Also being evaluated are the theoretical procedures for computing supersonic drag of complete configurations; additional approaches for improving supersonic and hypersonic lift-to-drag ratios; methods for calculating certain static and dynamic stability derivatives for the complete range of angle of attack at supersonic speeds; and an analysis of the distribution of loads on wings of fairly general planform in nonuniform supersonic flow fields. Most recently a general study of hypersonic flow problems has been completed and a research program concerned with specific problems of this speed range is being initiated.

The intellectual challenge presented by research work and the opportunity to contribute to the advancement of the science of aerodynamics are enhanced at Grumman by the chance to work with and advise men engaged in preliminary design and other development activities. This situation engenders an improved insight into the value of a particular research project and the course it should follow, and helps generate ideas for new projects.

The wind tunnel as a research tool is frequently available in those cases where theoretical analyses require supporting empirical data or where the nature of the project demands its use as a primary source of information. Grumman's extensive high-speed automatic computing facility, a part of the Research Department, is also readily accessible, and is of extreme value in obtaining numerical solutions to problems which previously were considered impractical. Finally, what is possibly the most liberal evening-school scholarship program now available provides ample opportunity to the research engineer to expand his background in and knowledge of his field and allied subjects.

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Smith, Stephen R., M.S. in M.E., Group Engr., Northrop Aircraft, Inc.

Spearman, Morris, B.S. in Ae.E., Head, Stability & Control, 4-ft. by 4-ft. Supersonic Pressure Tunnel, NACA (Langley Field).

Speciale, Juan, Tech. Adviser, Argentine Aeronautical Military Mission (New York).

Stephens, Malcolm A., Engrg. Specialist, Chance Vought Aircraft, Inc.

Stoeltzing, Wesley R., B.S. in M.E., Sect. Supvr., Radioplane Co.

Stone, Sanford H., M.S.E., Assoc. Prof., Dept. of Engrg., San Diego State College.

Szlenkier, Tadeusz, B.S. in M.E., Sr. Thermodynamics Engr., Lockheed Aircraft Co. (Marietta).

Tanner, Edward J., B. of M.E., Chief Propulsion Engr., The Glenn L. Martin Co.

Taylor, Richard W., B.S. in M.E., Chief of Flight Test, Boeing Airplane Co. (Wichita).

Webb, Howard M., M.S. in Ae.E., Pres. and Gen. Mgr., American Aerophysics Corp.

Wood, Norman E., M.S. in M.E., Research Engr., Rheem Manufacturing Co.

Wrigley, David, Sr. Engr., Special Products Div., American Motors Corp.

Transferred to MEMBER Grade

Bogart, Carl W., B.S. in Ae.E., Sr. Aerodynamics Engr., The Glenn L. Martin Co.

Dansby, Ted, Sr., M.S. in Ae.E., Sr. Aerodynamics Engr., Convair Div. (Ft. Worth), General Dynamics Corp.

Morgan, Arthur D., Jr., B.S. in Ae.E., Sr. Struct. Engr., Convair Div. (San Diego), General Dynamics Corp.

Mutch, Marvin H., Sr. Group Engr., Boeing Airplane Co. (Wichita).

Ness, Thomas E., A.A. in Ae.E., Sr. Flight Test Engr., McDonnell Aircraft Corp.

Richard, Charles H., B.S., Struct. Engr., Convair Div. (Ft. Worth), General Dynamics Corp.

Shugert, Richard F., M.S. in Mathematics, Airborne Systems Engr., Radio Corp. of America.

Small, Ronald J., B.S. in M.E., Proj. Engr., Colonial Aircraft Corp.

Tarbox, Jack M., B.S. in Ae.E., Prelim. Design Engr., Colonial Aircraft Corp.

Trueblood, Ralph B., B.S. in Ae.E., Proj. Leader, Massachusetts Institute of Technology.

Elected to Associate Grade

Ammer, Joseph, Jr., Design Draftsman, Dunbar Kapple, Inc.

Barron, Charles I., M.D., Medical Director, Lockheed Aircraft Corp. (Burbank).

Breneman, Kenneth D., B.S., Lt., USAF; Pilot (Bergstrom AFB).

Brooks, Roger R., B.S. in Ae.E., Aerodynamicist, McDonnell Aircraft Co.

Clarkson, Vernon W., Sr. Safety Engr., The de Havilland Co., Ltd.

Fisher, Philip D., B. of M.E., Analytical Engr., Turbomotor Div., Curtiss-Wright Corp.

Haines, Frank W., Capt., USAF; Aero. Engr. (McClellan AFB).

Hurst, Donald F., B.S. in Ae.E., Engr., Douglas Aircraft Co., Inc. (Long Beach).

Inman, Robert M., B.S. in Ae.E., Thermodynamics Engr., Lockheed Aircraft Corp. (Burbank).

Kane, Harry P., B.S., Sr. Field Engr., Philco Corp.

Luboyeski, S. Raymond, B. of M.E., Staff Engr., The Glenn L. Martin Co.

Malven, Charles J., Liaison Engr., Fairchild Camera & Instrument Corp. (Los Angeles).

Meinking, William F., Sales Engr., J. A. Keenth Co.

Meltz, Gerald, B.M.E., Research Engr., Hughes Aircraft Co.

Meyer, Rudolph C., M.S., Research Engr., NACA (Cleveland).

Rao, Cherukuri S., B.S. in Ae.E., Stress Engr., Canadair, Ltd.

Shannon, Floyd A., Asst. to Pres., Rotar-Craft Corp.

Smith, Anthony M., B.S. in M.E., Aerodynamics Engr., General Electric Co. (Philadelphia).

Transferred to Associate Grade

Adkins, Calvin, B.S. in Ae.E., Engr., Convair Div. (Ft. Worth), General Dynamics Corp.

Adornato, Rudolph J., B.S. in Ae.E., Struct. Flight Test Engr., Grumman Aircraft Engineering Corp.

Ammann, Victor R., Jr., B.S. in Ae.E., Assoc. Engr., Convair Div. (Ft. Worth), General Dynamics Corp.

Baldwin, Robert S., B.S. in Ae.E., Assoc. Engr., Convair Div. (San Diego), General Dynamics Corp.

Baron, Judson R., Sc.D., in Ae.E., Research Engr., Naval Supersonic Lab., Massachusetts Institute of Technology.

Bartle, E. Roy, M.S. in Ae.E., Staff Scientist, Convair Div. (San Diego), General Dynamics Corp.

Christoffersen, Glen R., B.S. in Ae.E., Assoc. Engr., Lockheed Aircraft Corp. (Sunnyvale).

Crestanello, James J., B.S. in E.E., 2nd Lt., USAF; Chief, Radio Engrg. Branch, 2720th Maint. Group.

Del Do, Louis J., B.S. in Ae.E., Proj. Officer, USAF (Wright-Patterson AFB).

Dodd, Walter O., B.S. in Ae.E., 2nd Lt., USAF Reserves.

Attention Members!

All Members of the Institute are invited to submit material concerning their activities for publication in the news columns of the *Aeronautical Engineering Review*.

Doshier, Kelsie W., B.S. in Ae.E., Design Engr., Cessna Aircraft Co.

Dulmovits, John, B.S. in Ae.E., Assoc. Engr., Northrop Aircraft, Inc.

Eisen, Dennis, B.S. in Ae.E., Graduate Student, Brown Univ.

Epstein, Melvin, M.S. in Ae.E., Sr. Scientist, Gruen Applied Science Lab., Inc.

Ferman, Marty A., B.S. in Ae.E., Graduate Student, Purdue Univ.

Gates, Donald R., Stress Analyst, Design Development Co.

Gilberman, Michael A., B.S. in Ae.E., Graduate Teaching Asst., Bureau of Research, Univ. of Alabama.

Guadagnini, Frank E., B.S. in Ae.E., Assoc. Engr., The Glenn L. Martin Co.

Harris, Charles E., B.S. in Ae.E., Struct. Engr., Convair Div. (Ft. Worth), General Dynamics Corp.

Herrera, Joe G., B.S. in Ae.E., Aerodynamic Engr., North American Aviation Inc. (Downey).

Hironaga, Thomas T., B.S. in Ae.E., Aerodynamics Engr., North American Aviation, Inc. (Downey).

Hoekstra, Paul W., B.S. in M.E., Assoc. Engr., Douglas Aircraft Co., Inc. (Santa Monica).

Hofferth, Delbert D., B.S. in Ae.E., Flight Test Engr., Douglas Aircraft Co., Inc. (Santa Monica).

Hofstadler, Hugo W., B.S. in Ae.E., Engrg. Officer, USAF; (Kirtland AFB).

Hollis, William C., B.S. in Ae.E.

Jones, Michael H., B.S. in M.E., Research Engr., ARO, Inc.

Landauer, Donald H., B.S. in Ae.E., Aerodynamics Engr., Republic Aviation Corp.

McKinney, Joe R., B.S. in Ae.E., Flight Test Engr., Temco Aircraft Corp.

Myers, Russell H., Jr., B.S. in Ae.E., Performance Engr., USAF (Edwards AFB).

Nichols, James O., B.S. in Ae.E., Instructor, Univ. of Alabama.

Painter, George H., III, B.S. in Ae.E., Loads Engr., McDonnell Aircraft Corp.

Parthasarathy, Rangaswamy, M.S. in Ae.E., Research Asst., New York Univ.

Petrick, J. Ronald, B.S. in Ae.E., Flight Test Control Engr., Convair Div. (Edwards AFB), General Dynamics Corp.

Pickett, Eugene C., Design Engr., Cessna Aircraft Co.

Ruelke, Franklin R., Assoc. Engr., Douglas Aircraft Co., Inc. (El Segundo).

Schalow, Peter S., B.S. in Ae.E., Assoc. Engr., Flight Test, Douglas Aircraft Co., Inc. (Santa Monica).

Smith, Charles E., Jr., B. of Ae.E., Advanced Study Engr., Missile Systems Div., Lockheed Aircraft Corp. (Van Nuys).

Thompson, Thomas R., M.S. in Ae.E., Member, Tech. Staff, The Ramo-Wooldridge Corp.

Wiser, Denzel N., B.S. in Ae.E., Advanced Study Engr., Missiles Systems Div., Lockheed Aircraft Corp. (Van Nuys).

New Vickers Airborne Electrical Power Package

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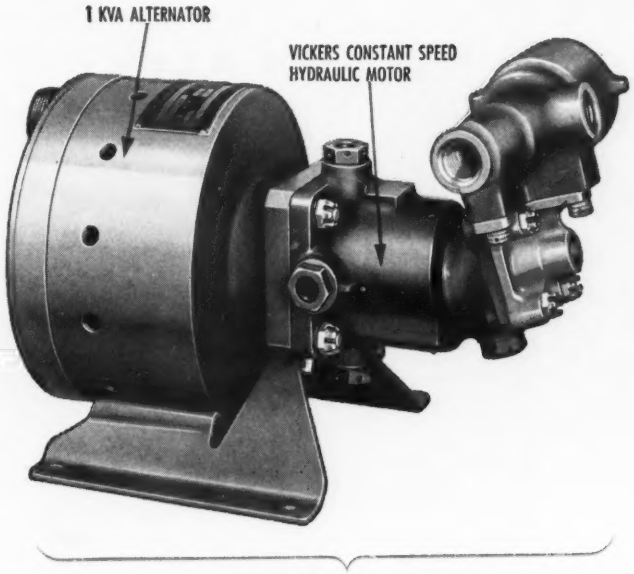
This new isolated electrical power package provides closely regulated AC power with minimum weight and envelope while drawing its power from a hydraulic system. In new designs or when adding electronic equipment to aircraft designs in which the electrical system is already loaded to capacity, this versatile package provides the needed AC power from flow available in the hydraulic system. This generally is permissible without system change as the full flow is seldom demanded except for a few seconds under rare circumstances. Even in such cases, full flow can be guaranteed to these hydraulic functions through the use of a simple priority valve which starves the AC power package momentarily.



TOTAL WEIGHT.....10.5 LB
OVERALL LENGTH...9 21/32 IN.

Less Weight and More Efficient

Important weight savings are achieved through the use of this package instead of an inverter which may also require an increase in the DC generator and line capacities. In one instance, the 10.5 lb 1 kva package replaced a 38 lb inverter for co-pilot instrumentation. An additional advantage is that the package has 62% overall efficiency while that of the inverter was 35-40%.

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Features of AC Generator

The permanent magnet type AC generator has excellent life and reliability. It requires no bulky voltage regulator . . . is inherently smaller and lighter than conventional generators due to the elimination of the exciter and slip rings. It also has higher overall efficiency resulting from elimination of all excitation losses. Additional advantages are that the permanent magnet is unaffected by momentary short circuit, or separation of field and armature without keeper, or by temperature cycling. It is also not susceptible to aging or shock. This unit is 120/208 volt, three phase, wye connected with 400 cps at 8000 rpm. It is capable of continuous duty under environments of 0-55,000 feet altitude and ambient temperatures from −65 F to 250 F.

Hydraulic Motor Drive

The generator is directly driven by a Vickers Constant Speed Hydraulic Motor having fixed stroke and an integral flow control valve that maintains an 8000 rpm speed setting within ±2½% regardless of the load (as long as valve inlet pressure is greater than load requirement). For the unit shown above, maximum operating pressure is 3000 psi while rated output of 1 kva requires operating pressure of 2200 psi. Special configurations will maintain 400 cps frequency within ±0.1% regardless of load. This motor has a very high horsepower-weight ratio and its overall efficiency exceeds 92%. It is a time-proved design capable of many hundreds of hours of continuous service without attention.

Many Uses and Sizes

The applications for this isolated power source are numerous. For multi-engine aircraft, its use for co-pilot instruments provides dual reliability. This package has been used to supply controlled frequency AC power in emergencies when the only source of power in the airplane is a ram air turbine driven pump. The efficiency of this arrangement minimizes the size and weight of the ram air turbine necessary to provide emergency hydraulic and electric power.

7492-R

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kva output	weight, pounds
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1.0	10.5
1.5	12.5
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2.5	17
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Larger capacities with minimum weight are available.

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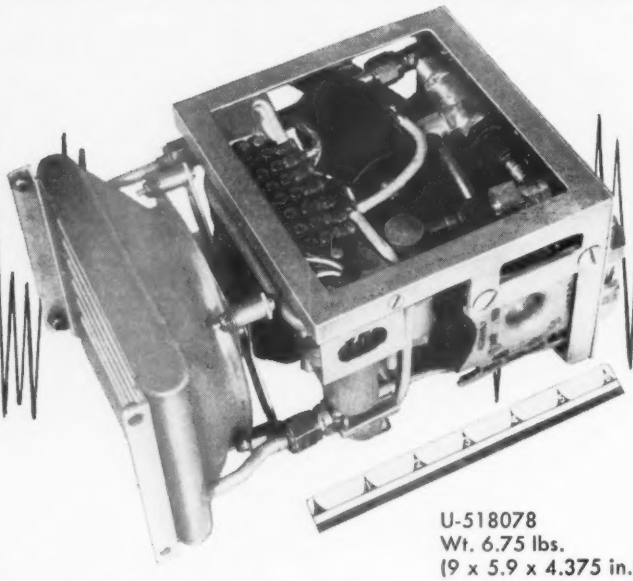

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A Guide to the Current Literature of Aeronautical Research and Engineering

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INTERNATIONAL AERONAUTICAL ABSTRACTS, published as an insert in each issue, is an accelerated reviewing service covering worldwide scientific and technical literature. This work is performed by the IAS Staff and is supported by the Air Force Office of Scientific Research of the Air Research and Development Command.

A list of the periodicals and reports series received in the IAS Library is published semiannually, in the January and July issues.

The AERONAUTICAL ENGINEERING INDEX, published since 1947, provides an annual cumulation of the materials reviewed in this section.

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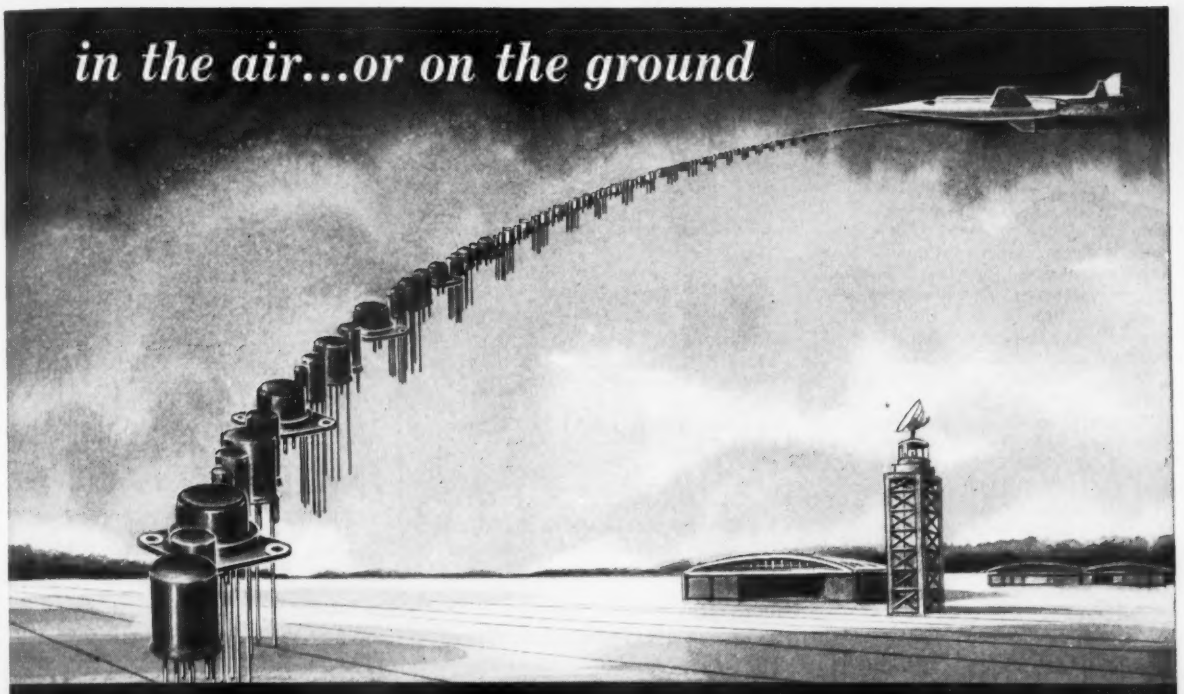

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ROCKET POWER PROGRESS REPORT

Taming Rocket Powerplants

by Walter O. Borcherdt

In charge of the Engineering Development Laboratory as well as the Valves and Controls Section at RMI, Mr. Borcherdt has over a decade of rocket experience. Before coming to RMI in 1951, he was senior project engineer on controls in the rocket department of Curtiss-Wright Corporation. Mr. Borcherdt received his degree in mechanical engineering from Stevens Institute of Technology in 1938.

Reliability of a rocket powerplant is the direct result of the simultaneously correct operation of all of its elements. Generally, this is assured by overcoming each element's own peculiar development problems. Among these elements is one type which has the interesting property of being composed of specific components, yet whose operational characteristics are significant only in the performance of the entire powerplant system. This element is the control system.

Present powerplant controls requirements are based on these straightforward, simple considerations:

1. **Prepare the powerplant for firing**
2. **Sequence and control the system to rated thrust**
3. **Vary thrust rapidly and safely as required**
4. **Shut down smoothly**

Step one may require the use of gas pressure regulators and relief valves to push the propellants safely from tankage to pumps. There must be switches and relays to indicate or control the valves which admit propellants to the gas generators and combustion chambers, and time delay cutouts to insure against unsafe accumulation of propellants.

In step two, ignition and combustion may be monitored to insure correct use of the high energy release rates. Turbines may be safely brought up to speed by throttling the propellants. Safety devices may be added to limit over-speed and avoid the danger of structural failure.

In step three, a controller (it may be hydraulic, electric, pneumatic, or a combination) is used to vary thrust. Here multiple loop servo systems are sometimes used to insure that thrust change rates, turbine speeds, vehicle acceleration or terminal velocity, and other parameters vary in a coordinated manner.

Finally, in multiple stage powerplants or piloted vehicles, the rocket engine must be shut down safely and the system automatically purged of propellant accumulations.

The successful implementation of these four steps involves the application of many devices of unique characteristics whose individual selection is intimately tied to the following question:

"What is the actual control system problem to be solved?"

Once this question is clearly and consistently defined, a tight performance envelope results. This makes the few possible solutions fairly obvious. The final stage is to apply the knowledge of a team of control specialists and proceed through the usual component development stages. At RMI, this team of specialists in controls engineering is made up of highly qualified mechanical, electrical and chemical engineers. These professional men have wide experience in the creation of control units and systems for rocket powerplants as well as other types of propulsion systems. However, there is a continuing need for qualified graduate engineers, able to participate in working closely with other groups of specialists, integrating the control system into the overall engine performance envelope.

The systems approach is of extreme importance to successful rocket powerplant control efforts. It is a standard approach of the RMI Controls Section. Sequence system design, switching circuit analysis, human engineering, feedback control methods, statistical procedures, information theory and latest research data on fluid flow control are among the techniques used. They are applied along with practical design concepts which result in the development of simple but effective controls systems.

If you desire one or more reprints of Mr. Borcherdt's article, or would like to receive further information about employment at RMI, write to our Information Services Coordinator. Reaction Motors, Inc., 22 Ford Road, Denville, New Jersey.

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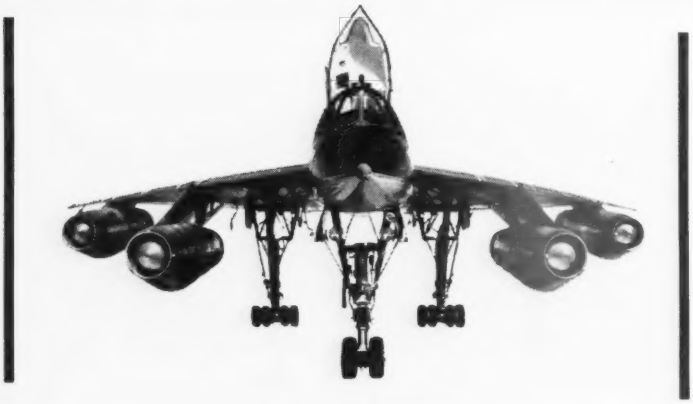

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Frequency Transformations and Dissipative Effects in Electric Wave Filters. D. J. H. Maclean. *Electronic Eng.*, Mar., 1957, pp. 108–114. Derivation of a general method, based on the zero-pole pattern of the lossless network, for estimating the effects of parasitic dissipation on the amplitude response of filters. Particular attention is directed to filters based on the common frequency transformations, and a new approach to these transformations is developed and used to derive the root pattern of a filter based on a low-pass equivalent. This pattern is applied in a relatively quick graphical estimation of dissipation effects.

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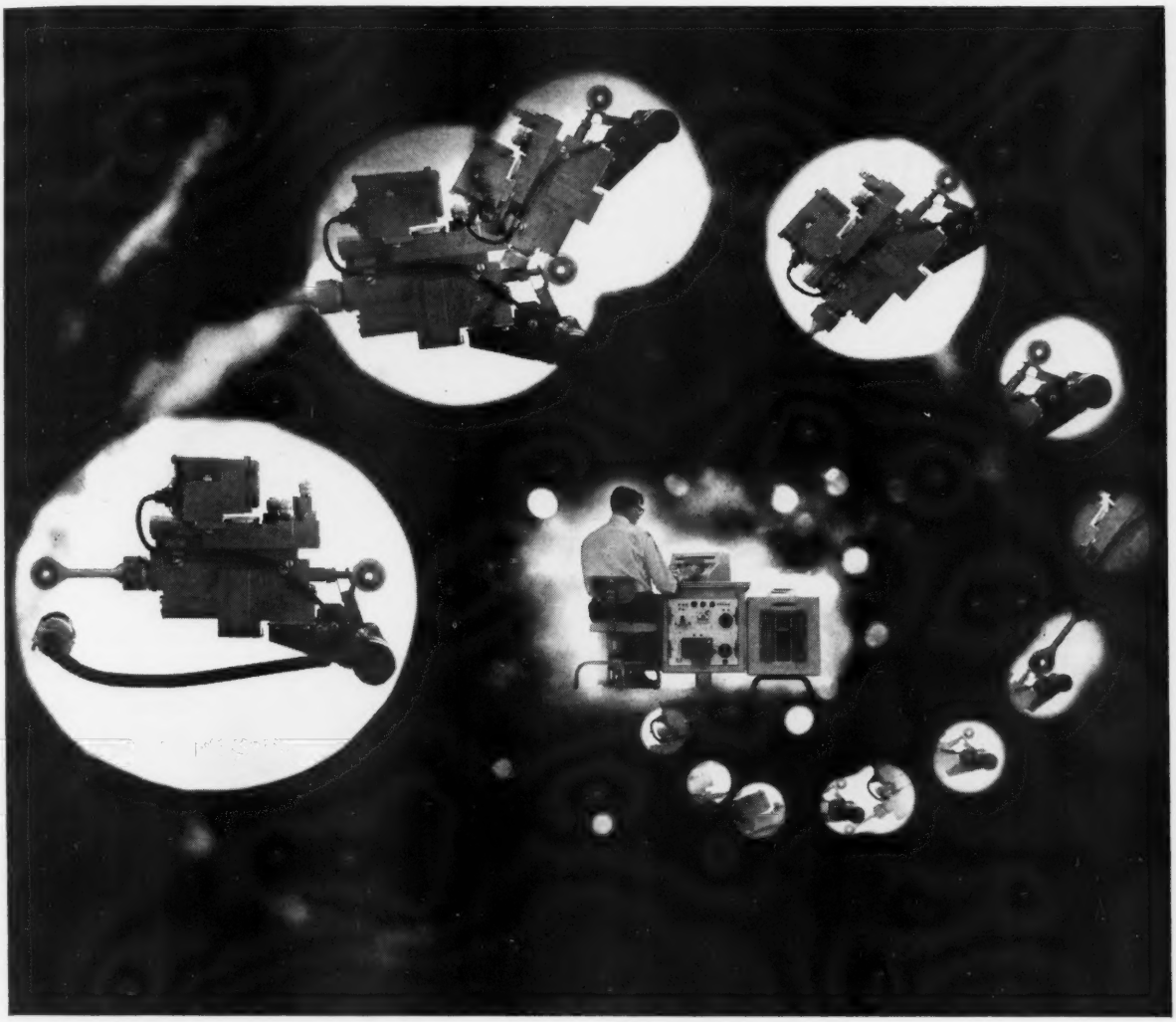

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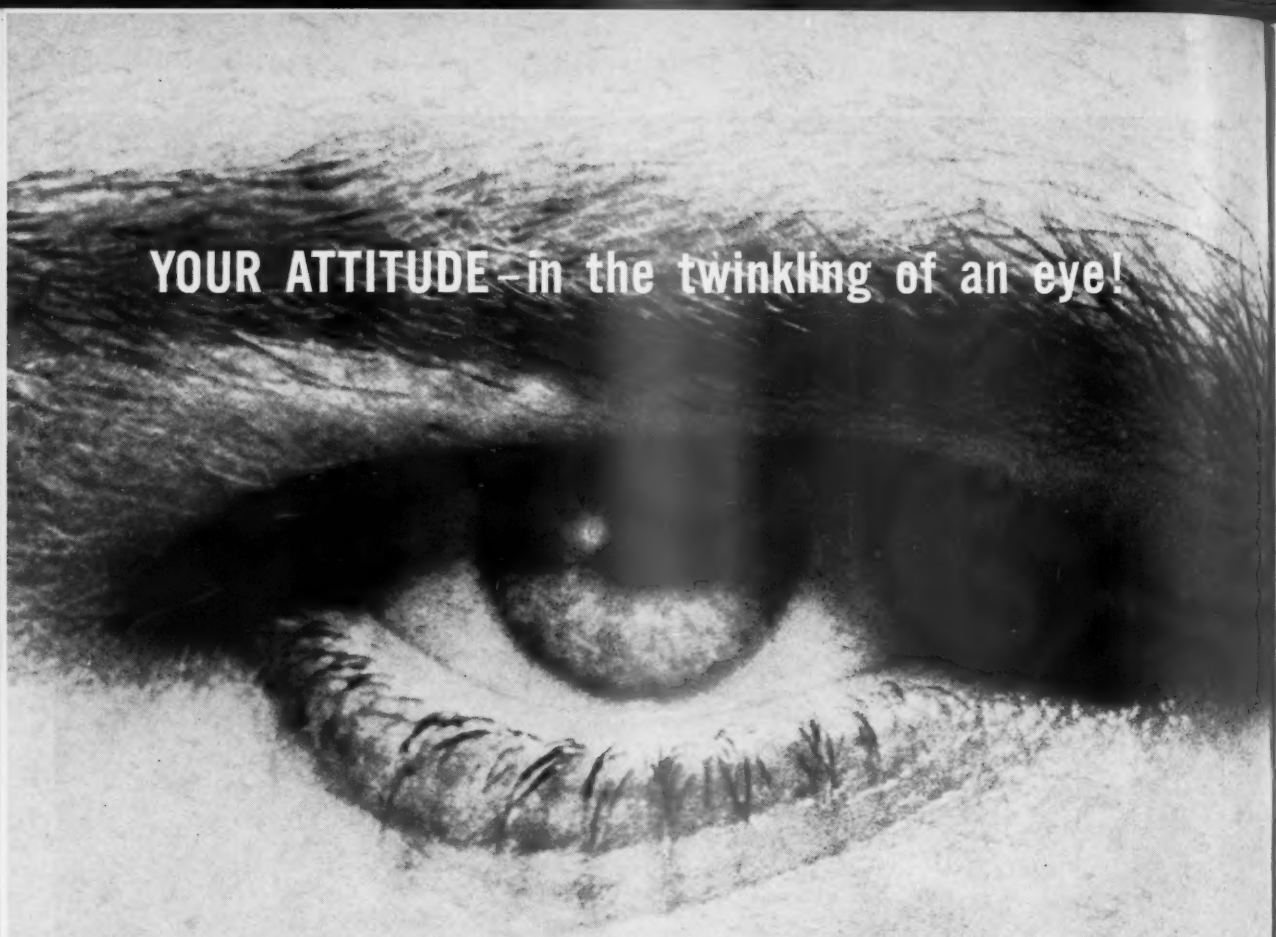

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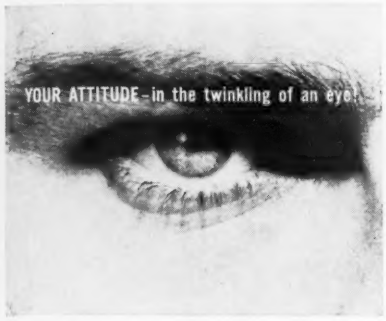

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case of a known transfer function or (b) the transfer function for the case of a given response function for stable linear automatic-control systems.

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This radical improvement in continuous detection is a small, flexible, seamless tube filled with an inorganic compound, with a nickel wire at its center, and a control unit that receives and amplifies electrical changes anywhere in the tube. Excessive heat anywhere along the tube lowers the resistance of the tube, and promptly triggers an alarm.

The Detector can be called a radical improvement for a number of reasons, but the basic reason is this: *the salt filler used by Fenwal gives such startlingly sharp drops in resistance with rising temperatures that the length of the loop hardly matters.* The temperature responses of a one-foot length and a twenty-foot length of the Detector tube are actually within 10° F of each other!

In short — the bugbear of almost all previous continuous fire detectors, so-called *averaging*, has been licked. With that bugbear licked, look at all the things Fenwal's new system can mean to aircraft safety!

CONTROL UNIT — Contains no components subject to wear or breakdown. Not bothered by shock and vibration. Not position sensitive. Hermetically-sealed. Weighs only 9 ozs.

No longer do alarm systems have to be set to trigger at dangerously high temperatures in order to minimize false alarming. Set to give the alarm at realistically low temperatures, the Fenwal system will not false alarm, and will give a true alarm instantly — giving precious seconds for remedial action.

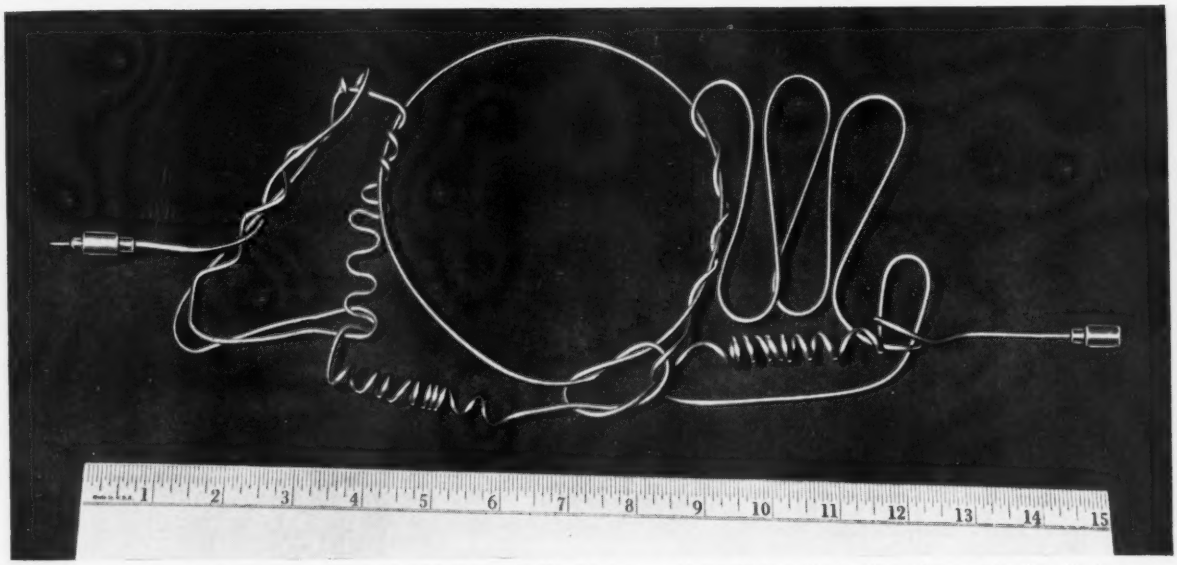
Wide-spread fire or over-heat conditions and localized hot spots trigger alarms at virtually identical temperatures.

Aircraft can now have continuous fire and over-heat detection that is, in effect, a network of unit detectors, monitoring a widely varying series of temperature situations. Lengths of sensing tube, each set to trigger the alarm at a different temperature, can be joined in a single loop, without one segment's affecting the performance of any other segment.

Fenwal has developed and tested exhaustively a large family of detectors for service over a range from 350° F to 2000° F.

The reliability and durability is due, in large measure, to the novel design of the control unit. The unit,

FIRE DETECTOR RELIABLE, ACCURATE



SELECTIVE, ACCURATE DETECTOR — So flexible it can be bent into any shape. Extremely low impedance virtually eliminates continuous-fire-detection bugbear of false alarming.

small enough to fit in the palm of a hand, is a hermetically-sealed magnetic amplifier which, when the alarm temperature is reached, amplifies the changes occurring in the detector loop and actuates alarms. It is light, tough, and not in the least position sensitive.

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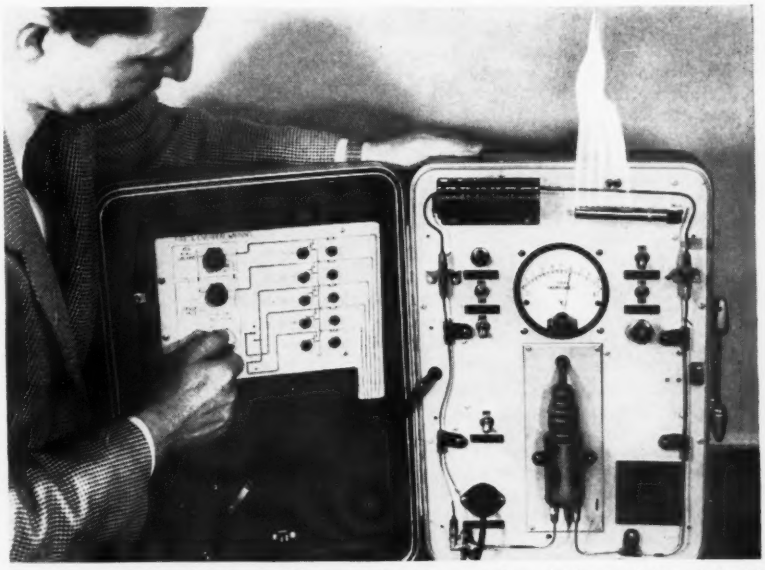

EXHAUSTIVE TESTS—Mock-up of detection loop (mounted on right panel) is tested with flame, demonstrates conclusively that it triggers alarm at same temperature despite variable ambient temperatures along loop and regardless of the length of loop exposed.

Mousley, F. Clifton, and D. Le Brocq. *Gt. Brit., RAE TN Struc.212*, Nov., 1956. 13 pp. Tests made with ordinary nuts alone, thin nuts alone, and a single nut and a thin nut locked together.

Gears & Cams

Impact Loads in Gear Trains; How to Evaluate Peak Torques and Stresses Caused by Sudden Stoppage. George Gorten. *Mach. Des.*, Mar. 7, 1957, pp. 83–87. Results of approximate and exact calculation methods compared to permit prediction of the modifying action of system elasticity on developed stresses. Includes examples for both methods.

Mechanisms & Linkages

Isochronism and Positional Regulation. Albert Dessay. (*5e Congrès Int. de Chronométrie*, No. 10, 1954, pp. 579–588.) *Gt. Brit., RAE Lib. Transl. 608*, Nov., 1956, 10 pp.

Seals

A Progress Report on Rubbing Seals. Gilbert C. Barnes and Earle A Ryder. *SAE Annual Meeting, Detroit, Jan. 14–18, 1957, Preprint 46.* 9 pp. Description of test apparatus for comparing wear qualities of various seal materials, and discussion of some of the test results.

Metal Dynamic Hydraulic Seals. George R. Keller and Paris H. Stafford. *SAE Annual Meeting, Detroit, Jan. 14–18, 1957, Preprint 45.* 7 pp. Discussion of the need for metal seals and analysis of the dynamic forces on a seal similar to a belleville spring.

Seal Leakage in the Rotary Regenerator and Its Effect on Rotary-Regenerator Design for Gas Turbines. D. B. Harper. (*ASME Diamond Jubilee Annual Meeting, Chicago, Nov. 13–18, 1955.*) *Trans. ASME*, Feb., 1957, pp. 233–242; Discussion, pp. 242–245.

Springs

Special Spring Forms. Frank A. Votta, Jr. *Mach. Des.*, Mar. 7, 1957, pp. 106–109. Presentation of four common types of specially shaped springs, their basic design formulas, and their principles of design application.

Supports for Vibration Isolation. W. G. Molyneux. *Gt. Brit., RAE TN Struc.211*, Nov., 1956. 19 pp. Description of an arrangement of conventional linear springs with a nonlinear stiffness characteristic that provides zero or very small stiffness for a limited range of movement. Includes discussion of various applications.

Materials

Role of Materials Research and Development in Aeronautical Progress. Marvin C. Demler. (*IAS 25th Annual Meeting, New York, Jan. 28–31, 1957.*) *ARDC News Serv. Rel. 25-57*, Jan. 29, 1957. 6 pp.

Airframe Materials. Frederick C. Krug. (*IAS 25th Annual Meeting, New York, Jan. 28–31, 1957.*) *ARDC News Serv. Rel. 1-57*, Jan. 29, 1957. 12 pp. Discussion of current and developable materials in terms of the importance of the length of their exposure to extreme heat, to highly corrosive materials, and to radiant energy; their physical and mechanical properties; and the phenomena of creep and fatigue.

Problems in Materials Utilization. Claude W. Kniffin. (*IAS 25th Annual Meeting, New York, Jan. 28–31, 1957.*) *ARDC News Serv. Rel. 3-57*, Jan. 29, 1957. 10 pp. Discussion of the need for the development of new materials to meet new operational environments.

Materials in a Nuclear Environment. A. J. Mione. (*IAS 25th Annual Meeting, New York, Jan. 28–31, 1957.*) *ARDC News Serv. Rel. 6-57*, Jan. 29, 1957. 12 pp. Presentation of cross sections of data for the effects of nuclear radiation on various classes of materials, both crystalline and noncrystalline; discussion of some conclusions, drawn from consideration of microscopic nuclear-radiation effects, which permit estimation of such effects on new materials and development of intrinsically radiation-resistant organic structures; and presentation of examples illustrating the use of materials in electronic components to show the application of radiation-effects testing to hardware development.

How Radiation Changes Materials. Michael Ference, Jr. *SAE J.*, Feb., 1957, pp. 49–53. Abridged. Discussion of radiation, what it is, what is meant by radiation damage, and how it affects metals, nonmetals, chemical reactions, and rubber.

Materials Approach to Advanced Weapon Systems. H. C. Sullivan. (*IAS 25th Annual Meeting, New York, Jan. 28–31, 1957.*) *ARDC News Serv. Rel. 7-57*, Jan. 29, 1957. 16 pp. Discussion of the need for new materials developed to meet the requirements of high-speed flight.

Corrosion & Protective Coatings

The Rokide Process. *J. SLAE*, Jan., 1957, pp. 6, 7. Discussion of a technique for applying protective coatings of high melting-point pure oxides, spinels, and other materials to metal surfaces.

Metals & Alloys

A Dictionary of Metallurgy. LII—We–Xe. A. D. Merriman and J. S. Bowden. *Metal Treatment*, Feb., 1957, pp. 73–80.

The Refractory Carbides. John T. Norton. *U.S., ONR Res. Rev.*, Feb., 1957, pp. 20–23. Basic discussion of the properties, development and uses of refractory carbides.

Materials—Key to Superspeed Aircraft. *ASTM Bul.*, Feb., 1957, pp. 18–20. Discussion of NACA research to find suitable materials to overcome aerodynamic heating.

Aircraft Power Plant Materials. Rodney A. Jones. (*IAS 25th Annual Meeting, New York, Jan. 28–31, 1957.*) *ARDC News Serv. Rel. 2-57*, Jan. 29, 1957. 12 pp. Discussion of materials capable of operating at temperatures above 1,700°F. These include molybdenum, cermets, refractory alloys, and ceramics.

Molybdenum for High Strength at High Temperatures. Robert R. Freeman and J. Z. Briggs. (*ARS 11th Annual Meeting, New York, Nov. 26–29, 1956.*) *Jet Propulsion*, Feb., 1957, pp. 138–147. Discussion of developments in applying molybdenum alloys to ram-jet structures and of expectations for the future of this effort.

Neutron Radiation Effects on Tensile and Impact Properties of ASTM-A302 B Steel. E. E. Baldwin. *Mech. Eng.*, Mar., 1957, pp. 261–265. Presentation of tensile and impact tests on manganese-molybdenum steel which show that separate and combined effects of temperature and radiation have only minor effects upon the tensile and impact properties of the steel.

Survey of Low-Alloy Aircraft Steels Heat Treated to High-Strength Levels. V—Mechanical Properties in the Presence of Stress Concentrations. George Sachs and E. P. Klier. *USAF WADC TR 53-254 (OTS, PB 121505*, $3.75.), Sept., 1954. 140 pp. 69 refs. Summary of the results of impact and notch-tension tests on high-strength steels.

The Principles of Dispersion Hardening Which Promote High-Temperature Strength in Iron-Base Alloys. E. E. Underwood, A. R. Elsea, and G. K. Manning. *USAF WADC TR 56-184*, June, 1956. 64 pp. 49 refs. Study of strength properties of an iron/20%-chromium base alloy as influenced by ternary additions of titanium, beryllium, or boron. Property changes in these single-phase alloys are followed by means of tensile, creep-rupture, and hot-hardness tests, augmented by some X-ray and internal-friction measurements.

Metals & Alloys, Nonferrous

The High Nickel Hydroxides; the Oxidation of Nickel II Hydroxide. W. Feitknecht, H. R. Christen, and H. Studer. (*Zeitschrift Anorgan. & Allgem. Chemie*, No. 283, 1956, pp. 88–95.) *Gt. Brit., RAE Lib. Transl. 610*, Nov., 1956. 8 pp. 10 refs.

Could Beryllium be Used as a Structural Material. George A. Hoffman. *Materials & Methods*, Feb., 1957, pp. 100–103. Discussion of the possible use of a metal with a density comparable to that of magnesium and with a modulus of elasticity four times as large as that of aluminum. The main disadvantages are the lack of ductility and toxicity.

Preliminary Investigation of the Effect of Surface Treatment on the Strength of a Titanium Carbide-30 Percent Nickel Base Cermet. Leonard Robins and Edward M. Grala. *U.S., NACA TN 3927*, Feb. 1957. 16 pp. Study to determine the room-temperature modulus of rupture and the impact strengths of a cermet under various surface treatments. These treatments include grinding, lapping, blast cleaning, acid roughening, and oxidizing.

Résultats Acquis en Matière d'Alliages Magnésium-Zirconium de Fonderie Destinés à la Construction Aéronautique. Raoul Pradeau. *Docaéro*, Jan., 1957, pp. 51–58. In French. Review of results on magnesium-zirconium alloys for aeronautical application.

Thermal Expansion of Some Nickel Alloys. Peter Hidnert. *J. Res.*, Feb., 1957, pp. 89–92. Review of the linear thermal expansion of some nickel alloys

(*Continued on page 200*)

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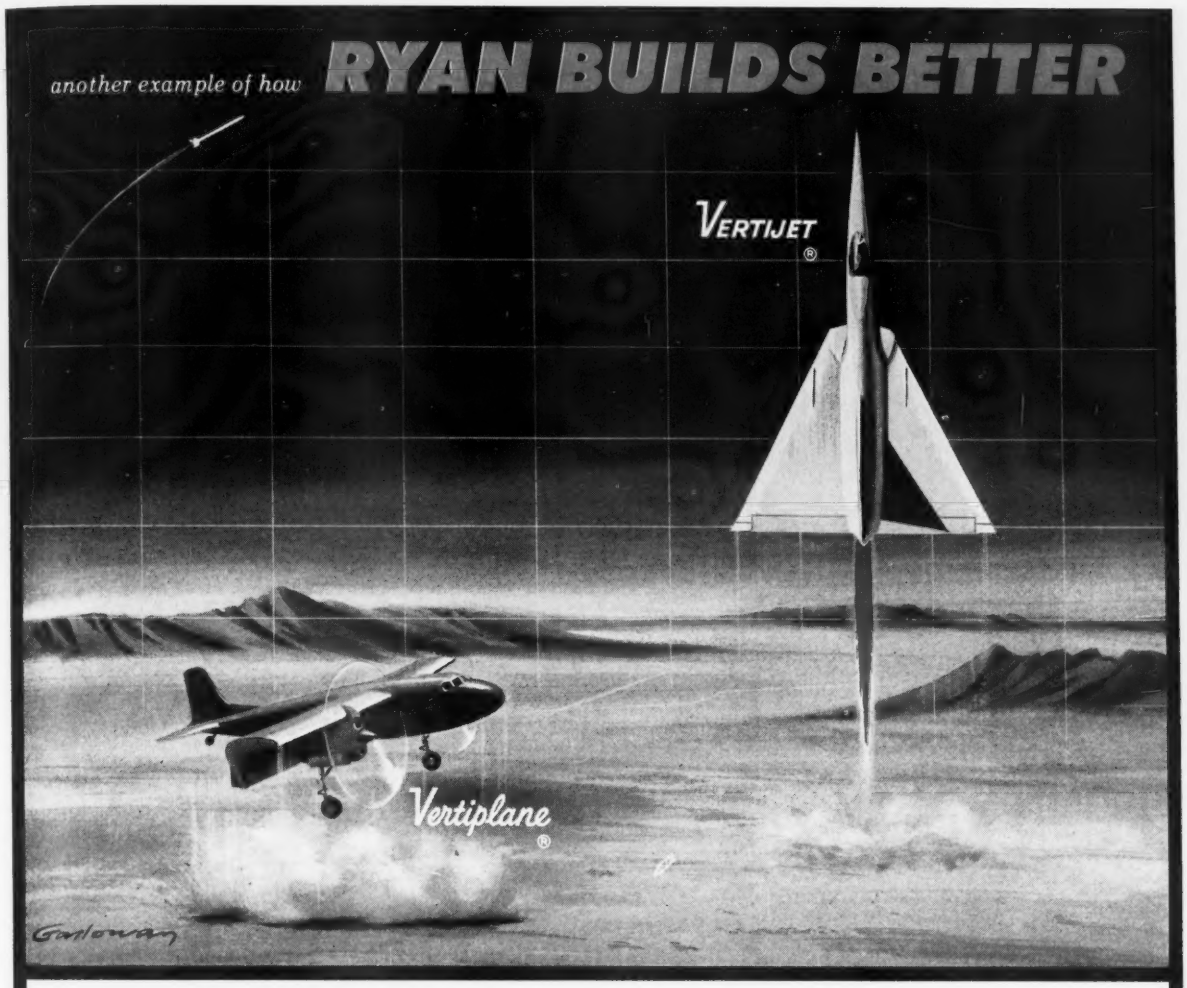

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Volume 2, Number 5 May, 1957

AERODYNAMICS

BEITRÄGE ZUM RANDWERTPROBLEM DER ELLIPTISCHEN TRAGFLÄCHE. H. G. Küssner. ZFW, Feb., 1957, pp. 50-56. In German. Derivation of a new integral representation of the pressure on an oscillating elliptic lifting surface for an incompressible fluid. Analysis employs orthogonal curvilinear coordinates and Lamé functions.

Aerothermodynamics

A NEW METHOD TO MEASURE PRANDTL NUMBER AND THERMAL CONDUCTIVITY OF FLUIDS. E. R. G. Eckert and T. F. Irvine, Jr. (ASME Annual Meeting, New York, Nov. 25-30, 1956.) J. Appl. Mech., Mar., 1957, pp. 25-28. 16 refs. Description of an experimental procedure based on the well-established, unique relation existing between the Prandtl Number and the recovery factor for laminar high-velocity boundary-layer flow. Includes description of the specially devised test arrangement, and experimental results for air at atmospheric pressure and temperatures between 60° and 350° F.

VELOCITY, TEMPERATURE, AND HEAT-TRANSFER MEASUREMENTS IN A TURBULENT BOUNDARY LAYER DOWNSTREAM OF A STEPWISE DISCONTINUITY IN WALL TEMPERATURE. D. S. Johnson. (ASME Annual Meeting, New York, Nov. 25-30, 1956.) J. Appl. Mech., Mar., 1957, pp. 2-8. 12 refs. OSR-supported mean-velocity and temperature-field measurements and determination of local heat-transfer-coefficient values in the streamwise direction in the region where the thermal boundary layer has not yet reached the free stream. The number of controlling factors is reduced by making the tests in an air flow having simple, reproducible boundary conditions and whose speed is low enough to permit neglect of the compressibility effect.

AN EXPERIMENTAL INVESTIGATION OF HEAT TRANSFER EFFECTS ON BOUNDARY LAYER SEPARATION IN SUPERSONIC FLOW. G. E. Gadd. J. Fluid Mech., Mar., 1957, pp. 105-122. 11 refs. Results of tests for wall pressure distributions through separated regions with both laminar and turbulent boundary layers at a free-stream Mach Number of about 3. The temperature of the flat plate on which the boundary layer is formed can be varied from about −35° C. to +75° C. According to theory, this variation should produce appreciable alterations at a laminar separation point in either the pressure or the pressure gradient, but no sign of this appears in the overall pressure distributions, which, for laminar layers, remains unaffected by wall temperature. It is concluded that, in supersonic separating flow with either a laminar or a turbulent boundary layer, the pressure distributions are not significantly affected by moderate variations in wall temperature.

TURBULENT MIXING OF TWO NON-REACTING GASES. L. G. Napolitano. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 323 (AFOSR TN 57-41) [AD 115079], Jan., 1957. 29 pp. Investigation of two-dimensional free turbulent mixing for two gases in the absence of axial pressure gradients. A linear dependence of mass concentration and stagnation enthalpy on velocity ratio is proved to exist when the turbulent Prandtl and Schmidt Numbers are both assumed to be 1. Two forms of the fundamental equation are derived under the hypothesis of constancy, along cross sections of the flow, for either the turbulent exchange coefficients or the mixing lengths. Several particular cases are examined and instances where the subject problem is reduced to well known solutions of turbulent mixing with uniformity in concentration are given.

Boundary Layer

THE NUMERICAL INTEGRATION OF THE LAMINAR COMPRESSIBLE BOUNDARY LAYER EQUATIONS, WITH SPECIAL REFERENCE TO THE POSITION OF SEPARATION WHEN THE

WALL IS COOLED. G. E. Gadd. Gt. Brit. ARC CP 312, 1957. 17 pp. BIS, New York, $0.54. Method for integrating boundary-layer equations when it is assumed that the external velocity at the leading edge of the boundary layer is not zero. Solutions are presented which are concerned with the position of separation under adverse pressure gradients. Two cases are presented. The first is for a Mach Number of 4, viscosity-temperature index (ω) and Prandtl Number (σ) equal to 1, and with constant adverse external velocity gradient. The second is for a Mach Number of two, ω and σ equal to 1, and with a constant adverse pressure gradient. In both cases the boundary layer is found to separate less readily then when the wall is thermally insulated.

TRANSITION, PRESSURE GRADIENT AND STABILITY THEORY. A. M. O. Smith and Nathalie Gamberoni. Douglas Rep. ES 26388, Aug. 31, 1956. 59 pp. 38 refs. Review and discussion of a method for predicting transition that is founded upon the theory of boundary-layer stability. It considers both plane and axially symmetric flows for a very low-turbulence incompressible stream past very smooth bodies. The theory states that disturbances in the boundary layer grow at the rate predicted by solutions of the Orr-Sommerfeld equation, with growth continuing until transition occurs.

AN APPROXIMATE METHOD FOR THE CALCULATION OF TURBULENT BOUNDARY LAYERS IN DIFFUSERS. J. F. Norbury. Aero. Quart., Feb., 1957, pp. 58-77. 10 refs. Analysis of boundary layers in which turbulence is developed before the commencement of the adverse pressure gradient. The method is based on a procedure of Spence which has been modified and extended to the calculation of three-dimensional diverging layers such as occur in ducts whose breadths are increasing. The velocity profiles occurring in a diverging layer are examined and it is shown that the inner part obeys the universal logarithmic law, as in two-dimensional layers. This result is used to obtain an equation for the form parameter $\gamma=(u/U)_{y=\delta}$ in diverging layers, by substitution in the equation of motion and incorporation of the equations of momentum and continuity for diverging flow.

THEORY OF THE FINITE-SPAN BLOWING WING. H. B. Helmbold. J. Aero. Sci., May, 1957, pp. 339-344, 370. Investigation of a finite-span blowing wing under the simplifying assumption of undisturbed static pressure at infinity downstream. The effects of finite span are induced drag and losses of jet thrust and jet-induced lift. The forces on the finite-span jet wing are functions of the induced angle which is determined either graphically, from a sixth-degree equation, or by a second-order approximation for moderate induced angles. The jet coefficients are represented as functions of jet-power coefficient and jet-sheet thickness ratio.

THREE-DIMENSIONAL WIND-TUNNEL TESTS OF A 30° JET FLAP MODEL. J. Williams and A. J. Alexander. Gt. Brit., ARC CP 304, 1957. 49 pp. BIS, New York, $1.44. Investigation to explore the effects of finite aspect ratio on the jet-flap scheme. Pressure plotting experiments are made on a model with a 12.5%-thick wing section. The spanwise distribution of pressure-lift loading induced by trailing-edge blowing is evaluated by chordwise integration of the surface static pressures, and closely follows what can be expected for a conventional wing at incidence without trailing-edge blowing. The total lift, drag, and pitching moments are derived for values of jet momentum coefficient (C_J) up to 2, at wing incidences between -5° and 20°, and up to 5° at zero incidence.

Fluid Mechanics & Aerodynamic Theory

DISSOCIATION EFFECTS IN HYPERSONIC VISCOUS FLOWS. Y. H. Kuo. J. Aero. Sci., May, 1957, pp. 345-350. Formulation of the boundary-layer flow problem for a gaseous mixture resulting from the dissociation of a single perfect diatomic gas. Under the assumption that the mixture is in dissociated equilibrium, the flow quantities, such as surface temperature, skin-friction, and heat-transfer coefficients, are evaluated and the importance of the transport coefficients (viscosity, conductivity, and diffusion coefficients) are examined. Results indicate that, under such a condition, the effects of dissociation on the transfer coefficients are not large at very high speeds.

DAMPING OF SURFACE WAVE IN AN INCOMPRESSIBLE LIQUID. K. M. Case and W. C. Parkinson. J. Fluid Mech., Mar., 1957, pp. 172-184. Calculation of damping in small amplitude surface waves for a liquid contained in a cylinder. Viscous dissipation in an assumed laminar boundary layer is taken to be the primary cause of damping. Experimental results are obtained for the logarithmic decrement as a function of the ratio of liquid height to cylinder radius for several water-filled cylinders. Theory and experiment are found to be in good agreement.

A STUDY OF SPRAYS FORMED BY TWO IMPINGING JETS. M. F. Heidmann, R. J. Priem, and J. C. Humphrey. US, NACA TN 3835, Mar., 1957. 32 pp. Investigation of two impinging liquid jets, over a jet velocity range of 5 to 100 ft./sec., to determine the characteristics of this method of atomization. At low velocities the spray pattern is a smooth sheet completely surrounded by a liquid rim. As the jet velocity increases, the rim separates at the downstream end. At higher jet velocities a fully developed spray is produced which is characterized by waves of drops. The wave pattern is more distinct with high-viscosity fluids. The frequency of the waves in the fully developed spray increases with increased injection velocity and decreasing impingement angle. Jet diameter and length before impingement have a negligible effect on the wave frequency.

FLOW WITH VARIABLE SHEAR PAST CIRCULAR CYLINDERS. J. D. Murray and A. R. Mitchell. Quart. J. Mech. & Appl. Math., Feb., 1957, pp. 13--23. Derivation of an exact solution

for stream flows for some variable shear flows past a circular cylinder. The shear distributions in the free stream are of the linear and boundary-layer type. In both flows the stagnation streamline is displaced in the free stream towards a region of higher velocity. This is in agreement with the results obtained previously for the case of constant shear flow past a cylinder and with the experimental results of Young and Maas for a pitot tube of circular cross section in a low-speed shear flow. The displacements in both variable-shear flows are comparable in magnitude to the values obtained in the constant-shear case, but are considerably smaller than the experimental values of Young and Maas.

INVESTIGATION OF SEPARATED FLOWS IN SUPERSONIC AND SUBSONIC STREAMS WITH EMPHASIS ON THE EFFECT OF TRANSITION. Appendix A - ANOMALOUS OIL-FILM OBSERVATIONS. Appendix B - SPECIAL EXPERIMENTS PERTAINING TO THE CROCCO-LEES THEORY. D. R. Chapman, D. M. Kuehn, and H. K. Larson. US, NACA TN 3869, Mar., 1957. 108 pp. 39 refs. Experimental and theoretical study of flow separation associated with steps, bases, compression corners, curved surfaces, shock-wave boundary-layer reflections, and configurations producing leading-edge separation. A theory for calculating dead-air pressure is derived for certain pure laminar separations in order to explain the experimental observation that transition location relative to reattachment is one of the two principal variables controlling pressure distribution (the other being transition location relative to separation position.) Theoretical work also includes a simple analysis of the equations for interaction of boundary layer and external flow near either laminar or turbulent separation, the results of which indicate that the pressure rise varies as the square root of the wall shear stress at the beginning of interaction. Experimental classification of each separated flow into one of three regimes leads to general results regarding the steadiness of flow and the influence of Reynolds Number within each regime. Includes discussion of the possible significance of an incidental analytical observation that the stability of a separated mixing layer increases markedly with an increase in Mach Number.

THEORETICAL AND EXPERIMENTAL ANALYSIS OF COWLING CONFIGURATIONS FOR THE REDUCTION OF THE DRAG ON A BODY OF REVOLUTION WITH LARGE CONE ANGLE. Luigi Broglio. Roma U. Sch. Aero. Eng. Inst. Aero. Construc. Rep. SIAR 7(AFOSR TR 57-2) [AD 115053], June, 1956. 47 pp. Investigation which shows that the total drag of a body can be reduced by using a suitable cowling ring. The function of the cowling is to increase static pressure on the back part of the body. If the angle of the leading edge of the cowling has a particular value, then the bow shock, after the intersection with the shock coming down from this leading edge, can be cancelled. Therefore the pressure rise is due only to the shock generated at the leading edge of the ring. The ring effect also acts favorably to decrease the base pressure drag. Analysis is based on the method of characteristics, performed for the cases of the body alone and body with cowling. Experimental results are given for various body configurations and cowling shapes.

THE INFLUENCE OF PROFILE THICKNESS ON RING AIRFOILS IN STEADY INCOMPRESSIBLE FLOW. Johannes Weissinger. USAF OSR TR 57-8 [AD 120424], Jan., 1957. 56 pp. Derivation of the source and vortex distribution of a symmetrical ring airfoil in axial flow. This distribution is determined by an integral equation, the kernel of which is tabulated. The axial velocity at a cylinder, covered with sources and vortices in such a way as to produce ring airfoils, is given in a form suitable for practical computation. These formulas have an explicit term and a second-order term. The latter term must be calculated by numerical quadrature using tabulated kernel functions; but in most cases it can be neglected because of its smallness. It is shown that the velocity at the profile may be calculated from these velocities at the circular cylinder.

RELAXATION PHENOMENA IN HYPERSONIC AERODYNAMICS. J. G. Logan, Jr. IAS 25th Annual Meeting, New York, Jan. 28-31, 1957, Preprint 728. 48 pp. 12 refs. Members, $0.35, nonmembers, $0.75. Discussion of recent investigations which indicate an earlier onset of dissociation for oxygen molecules than was previously indicated by theoretical considerations. Investigations are described which indicate relaxation times and relaxation path length for dissociation in oxygen of the same order of magnitude on those observed experimentally. In regions of large flow acceleration and rapid temperature drop, nonequilibrium flow conditions may be obtained with consequent influences on surface heat-transfer rates. Small decreases in lift may result for flow over airfoils, and effects are especially pronounced in the rapid expansions occurring in hypersonic nozzles.

A NEW APPROACH TO PROBLEMS OF SHOCK DYNAMICS. I - TWO-DIMENSIONAL PROBLEMS. G. B. Whitham. J. Fluid Mech., Mar., 1957, pp. 145-171. 15 refs. Analysis of the diffraction and stability of shock waves using an approximate theory in which disturbances to the flow are treated as a wave propagation on the shocks. These waves carry changes in the slope and the Mach Number of the shock. The equations governing the wave propagation are analogous to nonlinear equations for plane waves in gas dynamics, and their solutions can be deduced by the same methods. Specific problems analyzed include the motion of a shock along a curved wall, diffraction by a wedge, stability of plane shocks, and the instability of a converging cylindrical shock.

CORRELATION OF CONE-CYLINDER NORMAL FORCE AND PITCHING MOMENT DATA BY THE HYPERSONIC SIMILARITY RULE. Appendix - USE OF THE CORRELATION CHARTS. W. H. Dorrance and R. G. Norell. J. Aero. Sci., May,

1957, pp. 371-377, 392. 10 refs. Tests taken in the Naval Ordnance Laboratory 40- x 40-cm. wind tunnel, over a range of supersonic Mach Numbers, for the two-fold purpose of a) establishing the uniqueness of the hypersonic similarity rule and b) obtaining data for the preparation of normal-force and pitching-moment coefficient charts which can be used for any cone cylinder falling within the range of parameters of the charts.

THE REFLECTION AND TRANSMISSION OF SHOCK WAVES. I - THE REFLECTION OF A DETONATION WAVE AT A BOUNDARY. II - THE EFFECT OF SHOCK WAVES ON AN ELASTIC TARGET OF FINITE THICKNESS. D. C. Pack. Philos. Mag., 8th Ser., Feb., 1957, pp. 182-195. 12 refs. Analysis which shows that the nature of a reflected shock wave is uniquely determined by the relative shock impedances of the medium through which the incident wave passes, and the medium upon which it falls. Certain approximations, useful where there is a reflected shock wave, are discussed. An examination is made of the variation with time of the pressure and velocity in an elastic target of finite thickness subject to the impact of a shock wave. The cycle of reflections and transmissions at the boundaries of the target is described in detail.

MEASUREMENTS OF LIFT FLUCTUATIONS DUE TO TURBULENCE. Appendix A - SCALE OF TURBULENCE. Appendix B - SAMPLE CALCULATION OF ABSOLUTE AERODYNAMIC ADMITTANCE. P. Lamson. US, NACA TN 3880, Mar., 1957. 38 pp. Investigation of fluctuating lift on a rigid wing in turbulent flow by measurement of the power spectra of the lift and the turbulent fluctuations. From these measurements the aerodynamic admittance of the wing is obtained. The ratio of span to scale of turbulence is varied by means of movable end plates. For large ratios of span to scale of turbulence the aerodynamic admittance is decreased for all frequencies and becomes nearly independent of frequency in the investigated range. In general the measurements support the simplifying assumptions made in the statistical approach to gust loads and buffeting initiated by Clementson and by Liepmann.

A NUMERICAL METHOD FOR A CONVERGING CYLINDRICAL SHOCK. R. B. Payne. J. Fluid Mech., Mar., 1957, pp. 185-200. Analysis using the Lax's finite difference method to solve the equations of motion for a cylindrically symmetric flow of a compressible fluid. A converging cylindrical shock is found to increase in strength, agreeing with the formula of Chisnell.

Internal Flow

A THEORETICAL ANALYSIS OF THE VISCOUS FLOW IN A NARROWLY SPACED RADIAL DIFFUSER. H. W. Woolard. (ASME Annual Meeting, New York, Nov. 25-30, 1956.) J. Appl. Mech., Mar., 1957, pp. 9-15. 23 refs. Development of a method for calculating the radial pressure distribution for laminar viscous flow in a narrowly spaced radial diffuser having arbitrarily shaped walls deviating only moderately from a plane surface. The method is also directly applicable to turbulent flow in the initial inlet region of a diffuser.

TWO-DIMENSIONAL CONTRACTING DUCT FLOW. J. C. Gibbings and J. R. Dixon. Quart. J. Mech. & Appl. Math., Feb., 1957, pp. 24-41. 13 refs. Analysis of incompressible potential flow through two-dimensional contracting channels of finite length. These channel flows are obtained by first specifying flow patterns in the logarithmic hodograph plane. It is shown that some of these patterns can result in infinite values, at points on the channel wall, of both the velocity gradient and wall curvature. A method of avoiding these undesirable features is given which alters the contraction boundary so as to replace them by wall portions along which the velocity gradient is constant.

THE AERODYNAMIC VARIABLE NOZZLE. A. I. Martin. J. Aero. Sci., May, 1957, pp. 357-362. Derivation of first-order approximations for the aerodynamic quantities relating to a nozzle, into the main stream of which a thin layer of high-pressure air is injected, for the case where no heat exchange occurs between the air jet and the main stream. Both this case and the case where the air jet does mix with the main stream are treated by means of the theory of one-dimensional gas flow, and some of the results are compared with experimental data.

Stability & Control

THE TIME VECTOR METHOD FOR STABILITY INVESTIGATIONS. I - BASIC INFORMATION. II - LONGITUDINAL MOTION. K. H. Doetsch. Gt. Brit., ARC R&M 2945, 1957. 36 pp. BIS, New York, $1.89. Derivation of a semi-graphical method for dynamic stability analysis which is based on the concept of rotating time vectors. This concept has long been applied to oscillations of constant amplitude. Applications of the method are developed using the phugoid and short-period longitudinal oscillations as examples. The method emphasizes automatically the phase and amplitude relationships between the variables of the oscillatory motion.

DETERMINATION EN VOL DES DERIVEES AERODYNAMIQUES ET DE L'EFFICACITE DES GOUVERNES D'UN AVION A PARTIR DE SES REPONSES A DES SOLLICITATIONS HARMONIQUES ENTRETENUES PAR LE PILOTE. M. Scherer and P. Delaveault. La Recherche Aéronautique, Feb., 1957, pp. 13-19. In French. In-flight determination of aerodynamic derivatives and control effectiveness of an aircraft in terms of its response to harmonic control action performed by the pilot.

THE SPINNING OF MODEL AIRCRAFT AND THE PREDICTION OF FULL-SCALE SPIN AND RECOVERY CHARACTERISTICS. G. E. Pringle and D. J. Harper. Gt. Brit., ARC R&M 2906, 1956. 104 pp. 36 refs. BIS, New York, $6.30. Summary of dynamic scale model tests made between 1934-1947 to determine a method for the prediction of the probable spinning characteristics of a conventional

aircraft. Discussion includes the sensitivity of the spinning model to applied forces including those that upset the spin to produce recovery and those that alternatively generate a new spin. The difference between model- and full-scale spins is analyzed with a view to correcting the model data. Also included is a discussion of special aspects of the spin of tailless aircraft, and on special safety devices.

Wings & Airfoils

CALCULATION OF AERODYNAMIC FORCES ON SLOWLY OSCILLATING RECTANGULAR WINGS IN SUBSONIC FLOW. A. I. van de Vooren and E. M. de Jager. Netherlands, NLL TN F.192 (AFOSR TN 57-40) [AD 115078], Oct. 1, 1956. 69 pp. 14 refs. Method using a lifting-surface theory which takes into account the unsteady effects due to the wake. Results are given as series containing terms of increasing powers in reduced frequency. It is shown that if the axis of rotation is ahead of the airfoil, the aerodynamic damping is much less than it would be for quasi-steady theory. Instability is possible if the aspect ratio is larger than a certain value, but this limiting aspect ratio decreases with increasing Mach Number.

AERODYNAMIC FORCES ON AN OSCILLATING AEROFOIL FITTED WITH A SPOILER. L. C. Woods. Proc. Royal Soc. (London), Ser. A, Mar. 12, 1957, pp. 328-337. Analysis of an airfoil in an incompressible fluid with two vortex sheets trailing downstream, one from the trailing edge and the other from the point of flow separation on the upper surface. The separation point is assumed to be fixed during the oscillation, and the pressure on the free streamlines is taken as constant. Formulas for pressure distribution, lift and moment are obtained, and the effects of flow separation on the damping derivatives are illustrated by a number of graphs. It is found that a stalled or partially stalled airfoil has less aerodynamic damping than an unstalled airfoil.

DIREKTE BERECHNUNG VON TRAGFLÜGEL-PROFILEN AUS DER DRUCKVERTEILUNG. R. Eppler. Ing.-Arch., No. 1, 1957, pp. 32-57. 17 refs. In German. Derivation of simple formulas for the calculation of airfoil profiles from velocity and pressure distribution. The simplicity of these formulas permits a generalization of known types of laminar profiles. Includes illustrative application of the method.

INFLUENCE DU SOUFFLAGE AU VOISINAGE DU BORD DE FUITE SUR LES CHARACTERISTIQUES AERODYNAMIQUES D'UNE AILE AUX GRANDES VITESSES. Ph. Poisson-Quinton and P. Jousserandot. La Recherche Aéronautique, Feb., 1957, pp. 21-32. In French. Study of the influence of blowing in the vicinity of the trailing edge on aerodynamic characteristics of a rectangular wing of aspect ratio 3, in the Mach region between 0.6 and 2.5.

ETUDE THEORIQUE DE L'AILE ANNULAIRE. M. G. Faure. Tech. et Sci. Aéronautiques, No. 6, 1956, pp. 293-297. In French. Presentation of theoretical and experimental results on the circular wing. These results are limited to the case of subsonic incompressible flow, but the method presented can be extended to the subsonic compressible case, bounded by the validity of the linearized equation of the velocity potential. Biot and Savart's law is also used.

THE RING AIRFOIL WITH DEFLECTED CONTROL SURFACE IN STEADY INCOMPRESSIBLE FLOW. Johannes Weissinger. USAF OSR TR 57-8, Jan., 1957. 30 pp. Derivation of formulas for the distribution of radial force and pitching moment along the circumference of the airfoil, and for the total lift and pitching moment caused by the deflection of a control surface. Analysis uses the reciprocity theorem of wing theory in the special form for ring airfoils. Numerical results show a strong influence of ring shape (characterized by the length-diameter ratio $\lambda = L/D$) on the effectiveness of the control surface.

SOME REMARKS ON MULTHOPP'S SUBSONIC LIFTING-SURFACE THEORY. K. W. Mangler and B. F. R. Spencer. Gt. Brit., ARC R&M 2926, 1956. 9 pp. BIS, New York, $0.54. Development of an alternative to Multhopp's method for dealing with the spanwise integration to downwash. Instead of introducing an artificial correction function, the present procedure involves arranging the series form of the influence function near the inducing section to permit integration of the logarithmic term. Multhopp's scheme for the solution of the system of linear equations is, however, retained, and there is no increase in the amount of computer work entailed.

INCREASE IN LIFT FOR TWO- AND THREE-DIMENSIONAL WINGS NEAR THE GROUND. R. M. Licher. Douglas Rep. SM-22615, Oct., 1956. 45 pp. Analysis for the effects on the lift of a wing near the ground by replacing the ground with an image wing and by representing both real and image wings by networks of finite-strength bound and trailing vortices. For the two dimensional flat-plate wing, comparisons made with a known exact solution indicate that a set of finite-strength bound vortices can adequately represent the lift of the wing near the ground; however, the number of vortices used must vary with the distance above the ground. For the cambered two-dimensional wing, two different arrangements of the bound vortices are considered; these are believed to bracket the correct results, for which no exact solutions are now available. For the three dimensional wing, several simple networks of bound and trailing vortices are examined and compared with the theory of Tani. One calculation includes the effect of twist and taper.

THE CALCULATION OF MINIMUM SUPERSONIC DRAG BY SOLUTION OF AN EQUIVALENT TWO-DIMENSIONAL POTENTIAL PROBLEM. E. W. Graham. Douglas Rep. SM-22666, Dec., 1956. 38 pp. Investigation to find an analytical method

for determining the minimum possible wave-plus-vortex drag for a wing system for which the plan forms and relative locations of the wings are given, and which carries a prescribed total lift in supersonic flow. The wing systems studied include both planar and nonplanar wings, some wing combinations (such as biplanes), and certain wing-fuselage combinations. Results indicate that the proper adjustment of twist, camber, and thickness provides the minimum drag. Methods are developed a) for determining the minimum drag for a given total lift by solving a two-dimensional potential flow problem; b) for separating the wave and vortex-drag contributions; and c) for determining the optimum lateral (or spanwise) force distribution and the optimum projected singularities distributions used by Hayes for computing wave drag. Exact closed-form solutions are given for the case of the planar wing of diamond plan form with sonic edges and for that of the circular wing of constant chord.

NOTE ON THE EXTENSION OF EVVARD'S METHOD TO WINGS WITH SUBSONIC LEADING EDGES MOVING AT SUPERSONIC SPEEDS. G. J. Hancock. Aero. Quart., Feb., 1957, pp. 87-102. Extension of Evvard's technique by two different methods: (1) the relationships between the pressure loading and the integrals of the downwash over the wing surface are extended as far as possible, and (2) approximations are made for the upwash velocities in the neighborhood of the leading edge, resulting in a series of standard integrals for the estimation of the pressure loading. The latter method is applied to pressure loading on a flat-plate triangular wing and cropped delta wing, and the application to more general shapes is discussed.

CALCULATED AERODYNAMIC FORCES ON A SWEPTBACK UNTAPERED WING OSCILLATING IN INCOMPRESSIBLE FLOW. Appendix - DETERMINATION OF VIRTUAL INERTIAS BY THE VORTEX LATTICE METHOD. D. L. Woodcock. Gt. Brit., RAE Rep. Struc. 217, Dec., 1956. 21 pp. Analysis of air forces for a wing with 40° sweep and an aspect ratio of 2, oscillating with symmetric distortion modes. The results are presented both as influence matrices based on the displacement at a particular set of points, and also as overall derivatives for modes of the form $|\eta|^n$ when n = 0(1) 4 and where η is a nondimensional spanwise coordinate. The vortex lattice method is modified by making the size (in a chordwise direction) of the mesh, adjacent to the leading edge, smaller than that over the main part of the wing. Comparison is made with some values obtained by a variant of the Multhopp method, and agreement is found to be good.

AN INVESTIGATION AT LOW SPEED OF THE FLOW OVER A SIMULATED FLAT PLATE AT SMALL ANGLES OF ATTACK USING PITOT-STATIC AND HOT-WIRE PROBES. Appendix A - CORRECTIONS APPLIED TO THE PITOT-STATIC MEASUREMENTS FOR THE EFFECTS OF TURBULENT FLOW. Appendix B - CORRECTIONS APPLIED TO THE HOT-WIRE ANEMOMETER MEASUREMENTS FOR THE EFFECT OF LARGE VELOCITY FLUCTUATIONS. D. E. Gault. US,NACA TN 3876, Mar., 1957. 58 pp. 15 refs. Test results of measurements on the flow associated with the so-called thin-airfoil type of stall. The measurements are obtained for angles of attack of 2°, 4°, and 6° at a Reynolds number of 4×10^6. It is found that the large regions of reverse flow (bubbles) which are characteristic of the flow for a thin-airfoil stall cannot be considered regions of "dead" air. The reverse flow appears to be part of a more general circulatory or vortex-type flow. The largest velocity fluctuations are found to occur along a narrow band in the detached flow above the bubbles; these fluctuations amount to 0.3 of the free-stream velocity and are of the same relative magnitude as previously observed for a turbulent jet.

SUR LA THEORIE DE L'AILE EN DELTA; TOURBILLONS D'APEX ET NAPPES EN CORNET. Maurice Roy. La Recherche Aéronautique, Feb., 1957, pp. 3-12. In French. Development of the theory of delta wings and study of apex vortices and cone-shaped sheets. Includes review of investigations for the determination of a simplified theory in agreement with the characteristics of flow around delta and arrow-shaped wings and evaluation of flow-visualization techniques used in the ONERA hydrodynamic tunnel.

UNIFIED ANALYSIS OF AERODYNAMIC LOADS AT SUPERSONIC SPEEDS ON TRIANGULAR WINGS HAVING ARBITRARY CAMBER AND TWIST. J. H. Kainer and H. M. Grijalva. Convair Rep. ZA-251, Vol. I, II, Sept. 20, 1956. 395 pp. 37 refs. Investigation using linearized supersonic flow theory to determine the distributed and integrated forces and moments on triangular wings. Consideration is given to ten downwashes, including downwashes that are symmetric and those that are antisymmetric in relation to the spanwise coordinate, while the subsonic trailing-edge condition is neglected. The downwash is expanded in a power series proportional to $x^r y^s$ and the results include homogeneous cubics in the streamwise and spanwise coordinates ($0 \leq r + s \leq 3$). For given downwashes, 720 equations in closed form are tabulated for potential and pressure distributions at any point (x, y) and for spanwise distributions of lift, drag, pitching moment, and longitudinal centers of pressure. Results are in the form of 272 design charts for the downwashes considered. Includes illustrative examples.

DRAG OF A THIN BODY FAVORABLY INTERFERING WITH A WING IN SUPERSONIC FLOW. J. H. Clarke and F. D. Hains. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 310 (AFOSR TN 56-496) [AD 110310], Oct., 1956. 57 pp. 20 refs. Analytical comparison, using linearized theory, between the drags of thin, wing-like bodies and slender bodies of revolution when these bodies enclose the same volume and are immersed in the same supersonic stream. Interference of the biplane type between a high aspect-ratio wing and a thin, wing-like body of pentagonal plan form is analyzed - with the body considered to represent an external installation (such as a store

or winged vehicle) which is placed in proximity to the wing. Diaphragms and images are used to find solutions which indicate that, for the problem considered, interplanar induction is quasi two-dimensional in nature, so that all detailed calculations required are of the planar type. The difference between the wave drag of the configuration and that of the isolated wing is presented as a function of the body plan-form parameters for given values of the volume enclosed by the body.

AN EXTENSION OF MULTHOPP'S METHOD OF CALCULATING THE SPANWISE LOADING OF WING-FUSELAGE COMBINATIONS. J. Weber, D. A. Kirby, and D. J. Kettle. Gt. Brit., ARC R&M 2872, 1956. 24 pp. 14 refs. BIS, New York, $1.26. Description of a simple procedure applicable to wings of finite thickness, to root chords that are large compared with the body diameter, and to swept wings. The calculation, which can be performed in about one computer-day, is restricted to wings of moderate and large aspect ratios (above about 2).

FORCE AND MOMENT MEASUREMENTS ON A CONICAL BODY AND A RECTANGULAR WING, SEPARATELY AND IN COMBINATION, AT MACH NUMBER 1.94. Appendix - THEORETICAL ESTIMATES OF WING-BODY INTERFERENCE ON LIFT AND CENTRE OF PRESSURE. J. R. Anderson and D. Treadgold. Gt. Brit., ARC R&M 2864, 1956. 25 pp. 14 refs. BIS, New York, $1.26. Test results from lift, drag, and pitching-moment measurement made at small angles of incidence on two cones, three rectangular wings, and six derived cone-wing combinations. The agreement between theory and experiment for the lift of the isolated cones and wings is good but, for the drag and center of pressure, agreement is a little less satisfactory. The measured lift of the cone-wing combinations exceeds that estimated, while the measured center-of-pressure position agrees remarkably well with the estimated position. Agreement between measurement and theory for the lowest aspect ratio wing is improved when a correction is applied for the influence on the cone of the downwash generated by the cone.

AEROELASTICITY

EFFECT OF THERMAL STRESSES ON THE AEROELASTIC STABILITY OF SUPERSONIC WINGS. M. A. Biot. Cornell Aero. Lab. Rep. SA-987-S-2, Apr., 1956. 12 pp. Investigation to evaluate the influence of thermal stress on wing stability, including the chordwise bending, the anticlastic effects, and the nonlinear aspects due to finite deformation. The analysis employs a modified strip method which takes into account the influence of Poisson's ratio along with the membrane stresses. The temperature distributions are assumed to be parabolic along the chord and independent of the spanwise coordinate. For a positive temperature parameter τ the effect of the temperature is destabilizing with regard to torsional rigidity, and stabilizing with regard to the anticlastic effect. For the negative τ (cooling phase) the influence of the temperature on the stability is reversed.

OBOBSHCHENIE URAVNENII DINAMIKI SLOZHNOI ENERGOSISTEMY I PRIMENENIE ELEKTRONNOI SCHETNOI MASHINI DLIA ANALIZA USTOICHIVOSTI. L. V. Tsukernik. Avtomatika & Telemekhanika, Jan., 1957, pp. 47-58. 12 refs. In Russian. Generalization of differential equations of a complicated power system and application of an electronic digital computer to stability analysis.

SOME CONCEPTS AND PROBLEM AREAS IN AIRCRAFT FLUTTER. I. E. Garrick. IAS, SMF Fund Paper No. FF-15, Mar., 1957. 86 pp. 61 refs. Review of the historical developments and current trends in flutter. Several problem areas in the subsonic, transonic, and supersonic speed ranges are illustrated by specific examples or applications to simplified models. Some theoretical developments relating to linear and nonlinear lifing-surface theory for nonsteady flows are given. The role of the aeroelastic (flutter) model is discussed.

CRITERIA FOR THE PREVENTION OF FLUTTER OF TAB SYSTEMS. Appendix I - DERIVATION OF THE STIFFNESS MATRIX OF THE S-SYSTEM. Appendix II - DERIVATION OF THE RELATIONSHIP BETWEEN EQUIVALENT S- AND T-SYSTEMS. Appendix III - CONTROL EFFECTIVENESS OF A SPRING-TAB. Appendix IV - A NOTE ON STICK-FREE FLUTTER OF SPRING AND SERVO-TABS. H. Wittmeyer and H. Templeton. Gt. Brit., ARC R&M 2825, 1956. 44 pp. 12 refs. BIS, New York, $2.25. Theoretical investigation into the flutter characteristics of an idealized tab system in which the three degrees of freedom - normal translation of the lifting surface, rotation of the control surface, and rotation of the tab - are represented. Flutter-prevention criteria are derived for idealized forms of the standard trimming, spring, servo, and geared tab systems as represented by specific cases of the general ideal system, and the spring-tab criteria presently developed are compared with the existing Collar-Sharpe criteria. Design implications are deduced from the spring-tab criteria, whose applications to actual systems are considered in detail.

FLUTTER CALCULATIONS ON A RESONANCE MODEL DELTA WING. H. Hall. Gt. Brit., ARC CP 260, 1956. 18 pp. BIS, New York, $0.54. Theoretical investigation, based on the results of resonance tests on a dural model wing, to determine the effects of changes in inertia and stiffness on the flutter characteristics. Aerodynamic derivatives calculated by Woodcock for a delta wing are used and their application to the various modes is shown. Analytical results indicate that the forward movement of the inertia axis and increased stiffness of the wing spars are separately beneficial. The calculated flutter speeds are compared with flutter speeds given by formulas derived from earlier wind-tunnel tests on model delta wings and from experiments with ground-launched rockets. Qualitative agreement exists on the effects of the structural changes, but the absolute values of flutter speed differ appreciably. Possible explanations for the differences are discussed.

VIBRATIONS OF BEAMS. I - LONGITUDINAL MODES. G. J. Kynch and W. A. Green. II - TORSIONAL MODES. W. A. Green. Quart. J. Mech. & Appl. Math., Feb., 1957, pp. 63-78. 11 refs. Application of the second-order perturbation theory using known solutions for a circular cylinder to determine the wavelength frequency curves for the longitudinal vibration of a noncircular cylinder, and to determine the frequency equation, correct to the second order, for the first mode of torsional oscillations of the bar. Formulas are given in both cases for elliptic, square, and rectangular beams.

AIRPLANE DESIGN

CARAVELLE. Jules Jarry. Tech. et Sci. Aéronautiques, No. 6, 1956, pp. 251-273. In French. Presentation of design characteristics of the Caravelle aircraft, covering the aerodynamics of the wing, fuselage, and turbines. Includes data on transport aircraft having a pressurized cabin, with emphasis on fatigue resistance; test-flight measurements; and maintenance.

AVIATION MEDICINE

PROBLEMS OF VISION IN FLIGHT AT HIGH ALTITUDE. T. C. D. Whiteside. NATO AGARDograph 17, 1957. (London, Butterworths Scientific Publications; New York, Interscience Publishers, Inc. $5.00.) 162 pp. 83 refs. Experimental investigation considering: the effects of changes in intensity and spectral distribution of sunlight at high altitudes, in terms of the contrast between light and shade, fluorescence in the lens of the eye, and the intraocular scatter of light; physiological changes affecting the visibility of objects inside the cockpit, with reference to anoxia and glare; and the physiological factors affecting air-to-air visibility, in terms of the amount of accomodation exerted involuntarily in an empty visual field, the rate of relaxation of accomodation, the relation of the effectiveness of a stimulus at the far point to its angular distance from the fovea, a comparison of the effectiveness of six collimated patterns in bringing out accomodation for infinity, and the effect of empty-field myopia on the minimum visual angle for a distant target.

COMPUTERS

AN ANALOGUE COMPUTER FOR CONVECTIVE HEATING PROBLEMS. H. G. R. Robinson. Gt. Brit., RAE TN G.W.434, Oct., 1956. 24 pp. Description of a computer and applications to the flow of heat between a convective boundary layer and a wall having distributed conductivity and thermal capacity. The problem is simplified by reduction to three elements - the heat source, a transfer impedance, and the heat sink - and by a complete electrical analog of the heat equations.

ELECTRONICS

Cooling

ELECTRONIC EQUIPMENT COOLING BY SIMULTANEOUS HEAT AND MASS TRANSFER. A. R. Saltzman, B. T. Plizark, and L. F. Tomko. Aero. Eng. Rev., May, 1957, pp. 67-74. Description of a technique which allows heat to be transfered to an initially high-temperature air stream in such a manner that its exit temperature may actually be lowered below its inlet condition. The basic principles of simultaneous heat and mass transfer are applied to both one and two component cooling systems. The H.D.U. and H.T.U. cooling tower characteristics are introduced, and a procedure is presented for determining these characteristics for an evaporative-spray cooling-tower system to cool airborne electronic equipment.

Semiconductors

TRANSISTORS IN SERVO-SYSTEMS. A. G. Milnes. Gt. Brit., RAE TN El.129, Dec., 1956. 21 pp. 23 refs. Presentation of transient-response equations of a position-control servosystem taking into account the effects of rate-feedback and error-rate shaping. Amplifiers with either magnetic amplifier or transistor power stages are then discussed, and two new power output circuits with switched operation are described.

Wave Propagation

THEORETICAL RESEARCH ON MICROWAVE REFLECTING SURFACES - ABSORPTION OF MICROWAVES BY MILLIMETRIC COATINGS. Gaetano Latmiral. USAF RADC TN 57-80 [AD 114332], Sept. 30, 1956. 20 pp. Theoretical investigation of a single- or multiple-layer coating of millimetric thickness to achieve optimum minimization of reflections for both normal polarizations and those that are parallel to a plane of incidence. Analysis considers an electromagnetic wave in the range from 5,200 to 11,000 mc./sec., impinging on a perfectly conducting plane at incidence angles from 0^{o} to 90^{o}. The study is extended to theoretical materials that will provide 20 db. power attenuation for a frequency band 2:1 at incidence angles up to 65^{o}. A compromise solution for the problem of achieving total absorption in a limited frequency band is obtained by a simple nonmagnetic millimetric coating consisting of a lossy dielectric layer with a superimposed matching lossless dielectric layer.

THEORETICAL RESEARCH ON MICROWAVE REFLECTING SURFACES - MICROWAVE ABSORBING COATINGS. Gaetano Latmiral. USAF RADC TN 57-81 [AD 114333], Oct. 30, 1954. 16 pp. Theoretical investigation a) to find a combination of absorbing layers having a reflecting coefficient of less than 1% in power in the range 8,500 to 9,600 mc./sec. for a linearly polarized plane wave striking a plane surface, parallel to the wave front, at normal incidence; and b) to calculate the reflection coefficient of the above calculation at 1,000 to 10,000 mc./sec. The original surface is assumed to be perfectly conducting. It is shown that problem a) can be solved by using a simple thin coating consisting of a lossy dielectric layer and a superimposed matching lossless dielectric layer. Includes a practical example to illustrate the method.

INSTRUMENTS

Pressure Measuring Devices

AN ASSESSMENT OF THE ACCURACY OF A PRESSURE AND THRUST RECORDING SYSTEM EMPLOYING STRAIN GAUGE TRANSDUCERS, CARRIER AMPLIFIERS AND GALVANOMETER RECORDING. D. S. Dean and D. Young. Gt. Brit., RAE TN R.P.D.148, Nov., 1956. 34 pp. Experimental investigation to determine system accuracy prior to installation in a rocket-engine test bed. Each element of the system is checked individually for stability and reproducibility of the results. Where relevant, the accuracy of setting up the equipment and reading the results is determined. An estimate is then made of the accuracy to be expected with the complete equipment. Includes descriptions of modifications to overcome shortcomings in some of the instruments.

Stress & Strain Measuring Devices

MECHANICAL INTERFERENCE IN THE MEASUREMENT OF STRAIN. J. R. Linge. Aircraft Eng., Mar., 1957, pp. 70-74. Details of a simple extensometer with a gauge length of 0.50 in. which uses the mechanical interference of two sets of parallel straight lines as the means by which to measure displacement and, hence, strain. For development purposes, use is made of the interference effect exhibited by two pieces of Dufaycolor reseau placed in surface contact, as the reseau provides a convenient and ready-made source of fine parallel rulings, after removal of the photographic emulsion. Includes discussion of some related aspects of mechanical interferometry and its possibilities.

MATERIALS

Metals & Alloys, Nonferrous

THE FATIGUE STRENGTH AT FLUCTUATING TENSION (R = 0.1) OF REDUX BONDED 75 S-T CLAD SIMPLE LAP JOINTS FROM -45° C TO +80° C. A. Hartman and F. A. Jacobs. Netherlands, NLL Rep. M.2016, Aug., 1956. 26 pp. Fatigue tests to determine the influence of temperature on the fatigue strength of Redux-bonded joints. The adhesive is cured for a half hour at either 145° C. or 160° C. The results indicate that low temperatures have a favorable influence on fatigue strength. If the adhesive is cured for half an hour at 160° C., an increase in temperature from 20° C. to 50° C does not have any influence on the fatigue strength. At 80° C. joints cured at 145° C. have a low fatigue strength. At 80° C. the adhesive is unstable and continues to harden. This has a favorable influence on the properties at elevated temperature; the strength at room temperature is not impaired.

MATHEMATICS

NUMERICAL EXPERIMENTS IN POTENTIAL THEORY USING THE NEHARI ESTIMATES. U. W. Hochstrasser. US, NBS Rep. 5144 (AFOSR TN 57-91) [AD 120439], 1956. 12 pp. Investigation to determine how close Nehari's estimates for a number of harmonic boundary-value problems come to the actual errors in some particular examples. Several boundary-value problems are solved using Kopal's code for the orthonormalization of a given set of vectors on the NBS electronic automatic computer (SEAC) - the region being the same irregular pentagon in all cases. Consideration is given first to two problems whose exact solution is known, in order to provide a basis for comparison of the exact with the estimated error. The inquiry is carried out in such a way as to obtain empirically an understanding of how the results are affected by increasing the number of harmonic functions and by making a sophisticated choice of these functions.

CONFORMALLY INVARIANT WAVE EQUATIONS FOR NON-LINEAR AND INTERACTING FIELDS. J. A. McLennan, Jr. Lehigh U., Inst. Res. AFOSR TN 57-26 [AD 115061], Nov. 16, 1956. 12 pp. Derivation of nonlinear conformally invariant wave equations for spinors of arbitrary rank. These include an equation recently proposed by Gürsey. In addition, conformally invariant equations for interacting fields are given.

ESTIMATIONS OF ERROR FOR NONLINEAR ELLIPTICAL DIFFERENTIAL EQUATIONS. Alfred Meyer. USAF OSR TN 57-2 [AD 115032], Oct., 1956. 49 pp. Analysis which shows that the boundary-value problem with an elliptical differential equation is of the monotonous type, and therefore bounds can be obtained for its solution. Formulas which allow the estimation of error are given and applied to some examples.

MECHANICS

STUDIES ON THE ACCELERATION OF A BODY FROM REST. I - THE APPROXIMATE CONSTANCY OF VELOCITIES PRODUCED BY TIME-DEPENDENT ACCELERATIONS HAVING EQUAL MAXIMUMS AND OPERATING OVER EQUAL DISTANCES. J. L. Hess. Douglas Rep. ES-26463, Nov. 15, 1956. 22 pp. Analytical calculations for two representative classes of accelerations, discussion of the reasonableness of the conclusions for more general accelerations, and consideration of experimental data - all serving to indicate that, if a body is accelerated from rest through a fixed distance by accelerations having the same maximum value, the final velocities will differ very little, regardless of the shape of the acceleration-vs.-time curve. Conclusions are drawn from this fact which have direct bearing on ejection-seat design as well as more general applicability.

MILITARY AVIATION & ARMAMENT

BOMBING PROBLEMS - A STATISTICAL APROACH. A. G. Laurents. Operations Res., Feb., 1957, pp. 75-89. 33 refs. Study of bombing problems from the viewpoint of statistical inference, with given probability of a hit inside a circle centered at the target. Includes a method for obtaining the best estimate of the probability of a hit in a given area, with a known or unknown target, on the

basis of the information given by the points of impact during a flight.

MISSILES

INERTIAL GUIDANCE. Walter Wrigley, R. B. Woodbury, and John Hovorka. IAS 25th Annual Meeting, New York, Jan. 28-31, 1957, Preprint 698. 68 pp. 27 refs. Members, $0.50; nonmembers, $0.85. Analysis of the principles of inertial guidance in which position near the surface of the Earth is given by on-board measurements of time, gravity, acceleration, and angular velocity without the use of any radiation data. All of these parameters require continuous vector measurements in a three-dimensional coordinate frame. The direction of the force of gravity is the prime local parameter, and its dynamic measurement combines gravity and vehicle acceleration as two dynamic aspects of the same physical phenomenon. The proper instrumentation of these coupled effects results in Schuler tuning. Azimuth indication is also required. Guidance direction-indication involves comparing the direction or motion of local gravity with an inertially maintained reference. The change needed in the basic system when thrust rather than lift is the only important force is also considered.

DYNAMICS OF A SPINNING ROCKET WITH VARYING INERTIA AND APPLIED MOMENT. Kenneth Jarmolow. J. Appl. Phys., Mar., 1957, pp. 308-313. Analysis for the dynamic motion of a spinning rocket under the influence of varying moments of inertia resulting from the rapid expenditure of fuel, and a varying torque produced by a constant rocket thrust asymmetrically applied while the body center-of-gravity location varies as the fuel burns. Aerodynamic forces are assumed negligible. The resulting motion is described in terms of Euler angles and resembles the motion of an ordinary top with nonsteady precession. The motion is compared to that of a body of fixed moments of inertia caused by a torque of fixed magnitude. It is shown that the variable aspects of the general problem create important characteristics of the resulting motion.

PHYSICS

IRREVERSIBLE STOCHASTIC THERMODYNAMICS AND THE TRANSPORT PHENOMENA IN A REACTING PLASMA. H. J. Kaeppeler and G. Baumann. Forschungsinst. für Phys. Strahlantriebe, Stuttgart, Mitteil. 8 (AFOSR TR 57-20) [AD120462], Nov., 1956. 104 pp. 123 refs. Analysis of the equilibrium behavior of a plasma in order to develop a theory of transport phenomena in a reacting plasma at elevated temperatures. The equilibrium considerations concern the influence of electrostatic microfields on plasma properties, the termination of the electronic partition function, and the determination of the plasma composition. The classical diffusion theory of energy transport is discussed and an attempt is made to establish the rudiments of a stochastic description of plasma physics, with particular attention given to the thermodynamic aspects of transport phenomena. The theory derived is shown to include the purely statistical methods. The formal kinetic theory due to Wang-Chang and Uhlenbeck is extended for the calculation of internal energy transport, and approximate methods for integrating the collision integrals are derived. Analysis includes treatment of the energy transport in the presence of chemical reactions.

ZUR KENNTNIS STARK DISSOZIIERTER GASE. Eberhard Büchner and Reinhold Strobel. ZFW, Feb., 1957, pp. 33-43. In German. Discussion of some of the properties of dissociating gases. The enthalpy and entropy difference from the selected zero position (state of the gas at a temperature of 2,000°K. and a pressure of 1 kg./cm^2, ignoring dissociation) are calculated for a diatomic gas from the theoretical composition of dissociated and nondissociated parts. A combustion gas consisting of 3.852 gram-atoms hydrogen and 3.326 gram-atoms oxygen per gram-atom carbon is considered as a compound system. Relations between the coefficient of mol numbers (defined as the quotient of the sums of mol numbers with and without dissociation) and the dissociation part of the enthalpy are pointed out, giving the range of applicability of the Wagner formula. In both examples the isotherms show a reversal of slope in the enthalpy-entropy diagram.

POWER PLANTS

Jet & Turbine

EXPERIMENTAL INVESTIGATION OF TEMPERATURE FEEDBACK CONTROL SYSTEMS APPLICABLE TO TURBOJET-ENGINE CONTROL. Appendix A, B - METHOD OF OBTAINING ENGINE DYNAMICS FROM FREQUENCY-RESPONSE DATA. C. E. Hart, L. M. Wenzel, and R. T. Craig. US, NACA TN 3936, Mar., 1957. 56 pp. Study to determine some of the characteristics and capabilities of temperature feedback controls. The ability of the control system to control temperatures during transient operation is evaluated by considering time integrals of the functions of temperature error as well as overshoot ratios and response times. In the high-speed operating region tail-pipe temperature can be satisfactorily controlled during small transients by using systems which vary either fuel flow or exhaust nozzle area. A proportional-plus-integral control in a temperature-fuel-flow control system provides satisfactory transient response to a desired step increase in temperature. For a temperature-area control system it is necessary to add nonlinear components to the basic proportional-plus-integral control to provide satisfactory temperature response during transients.

TEMPERATURE EFFECTS IN A TURBO-JET ENGINE NOZZLE BLADE DURING TRANSIENT OPERATION. H. Taylor, R. E. Wilsdon and M. R. Abbott. Gt. Brit., NGTE Rep. R. 191, Jan., 1957. 83 pp. Experimental investigation in which nozzle blade temperatures are measured at four stations in the blade section during a variety of operating conditions. Shutdown from full speed is establish-

ed as the most severe case. Theoretical calculations are made of blade temperature, based on equilibrium heat transfer data, in order to explore the validity of a quasi-static approach to the transient-temperature problem. Reasonable correlation is obtained between calculated results and the engine experiment. A tentative estimate of blade-surface stresses in the cascade suggests that the maximum transient value is not reached until 4 sec. in the leading edge, and 8 sec. in the trailing edge after shutdown.

TESTS CONCERNING NOVEL DESIGNS OF BLADES FOR AXIAL COMPRESSORS. I - BLADES DESIGNED FOR INCREASED WORK AT ROOT AND TIP. II - BLADES DESIGNED TO OPERATE IN A PARABOLIC AXIAL VELOCITY DISTRIBUTION. Appendix I - DESIGN OF THE FREE-VORTEX COMPRESSOR BLADES. Appendix II - DESIGN OF V.W.D. COMPRESSOR BLADES. Appendix III - DESIGN OF V.A.P. BLADES. S. J. Andrews, R. A. Jeffs, and E. L Hartley. Gt. Brit., ARC R&M 2929, 1956. 22 pp. BIS, New York, $1.17. Test results on two sets of blades showing that neither set gives improved performance. Of the two methods attempting to improve the efficiency of the compressor by eliminating the secondary effects, the first method (Variable Work Done) shows the most promise. It is suggested that the reason for the partial success of the Variable Work Done blades is that by designing in this way, the energy can be restored to the air continuously at the position at which it is being dissipated by shed vortices and by the building up of the boundary layer.

Rocket

COMBUSTION PROCESSES IN LIQUID PROPELLANT ROCKET MOTORS (Fifth Quarterly Progress Report for the Period 1 September 1956 to 31 December 1956). I. E. Smith and I. Glassman. Princeton U. Dept. Aero. Eng. Rep. 334-e, Mar. 7, 1957. 16 pp. Test results on a low-pressure flow-type reactor for reaction-rate determinations, and discussion of the design of a high-pressure reactor for determining overall rates. The temperature history for the decomposition of gaseous ethylene oxide, injected into a heated, flowing, inert gas in the temperature range of 1,190° F. to 1,520° F., is followed using fine thermocouples. Typical records showing induction and reaction periods are presented. From the results the activation energy and overall reaction order are calculated over this temperature range.

AN APPROXIMATE MEANS OF DETERMINING THE AXIAL FLAME TEMPERATURE PATTERN WITHIN A ROCKET ENGINE COMBUSTION CHAMBER. L. J. Purchase and H. Walder. Gt. Brit., RAE TN R.P.D.149, Nov., 1956. 15 pp. Experimental method using metal rods of different melting points encastered at one end of the injector plate so that they lie parallel and close to the axis of the combustion chamber. The length of each rod remaining after the test gives an indication of the temperature at particular points within the chamber.

PROPELLERS

THE "LINEARIZED INFLOW" PROPELLER STRIP ANALYSIS. Appendix I - DERIVATION OF FUNDAMENTAL RELATIONS FOR THE LINEARIZED INFLOW STRIP ANALYSIS. Appendix II - EXPLANATION AND/OR SOURCE OF ITEMS IN THE LINEARIZED INFLOW STRIP ANALYSIS. Appendix III - EXAMPLE PROBLEM USING THE LINEARIZED INFLOW STRIP ANALYSIS. Appendix IV - MODIFICATIONS IN THE LINEARIZED INFLOW STRIP ANALYSIS FOR DETERMINATION OF NORMAL AND CHORDWISE PROPELLER BLADE FORCES. J. P. Cooper. USAF WADC TR 56-615 [AD 118078], Feb., 1957. 44 pp. Description of a method which, for simplicity, uses a linearized approximation to the induced propeller inflow. The information which is presented in the form of aerodynamic data, problem work sheets, and sample problems is sufficient for performance calculations for single rotation propellers operating at subsonic tip velocities and advance ratios of approximately 0.8 or greater. Includes additional data for supersonic section velocities.

ROTATING WING AIRCRAFT

HELICOPTER ROTOR BLADE FLAPPING AND BENDING. I - RIGID BLADE MOTION. J. P. Jones. Aircraft Eng., Mar., 1957, pp. 64-66. Description of a method for calculating rapidly the higher harmonics of rotor-blade flapping and bending. The procedure eliminates the need for solving large numbers of simultaneous equations and makes it possible to complete most of the calculation without introducing the actual value of the tip-speed ratio.

SECOND HARMONIC CONTROL ON THE HELICOPTER ROTOR. W. Stewart. Gt. Brit., ARC R&M 2997, 1957. 15 pp. BIS, New York, $0.90. Analysis of second harmonic controls which cause the redistribution of the loading over the rotor disc and can be utilized to postpone the forward speed limitations due to stalling of the retreating blade. A theory is developed for calculating the flapping and incidence distribution imposed on a rotor by a second harmonic control. It is found that the flapping amplitude and phase angle depend mainly on blade-inertia number and to a small extent on tip-speed ratio. A rotor tower test shows excellent agreement with the theory.

SPACE TRAVEL

THE EROSION OF METEORS AND HIGH-SPEED VEHICLES IN THE UPPER ATMOSPHERE. Appendix A - MINIMUM AND MAXIMUM VELOCITY OF METEORS. Appendix B - HEATING OF METEORS AND RADIATION LOSSES. C. F. Hansen. US, NACA TN 3962, Mar., 1957. 38 pp. 22 refs. Theoretical investigation using a simple, inelastic model of meteor-atmosphere interaction to derive analytic relations for velocity, deceleration, size, and relative luminous magnitude of meteors, and to express these relations in dimensionless parametric form. The analysis is compared with available quantitative observations of meteor be-

havior, and it is indicated that a large fraction of the atmospheric bombardment energy is used in eroding meteor material. The erosion from large, high-speed vehicles as they traverse the high-altitude, free-molecule portion of the atmosphere is calculated, on the assumption that the vaporization is similar to that occurring for meteors. It is shown that the maximum erosion does not create significant mass loss.

VELOCITY OF A BODY FALLING THROUGH THE ATMOSPHERE AND THE PROPAGATION OF ITS SHOCK WAVE TO EARTH. G. V. Groves. J. Atmos. & Terrestrial Phys., Feb., 1957, pp. 73-83. Theoretical investigation to find a solution for the velocity of a body falling to earth from a point outside the atmosphere. It is assumed that the flight path is a straight line inclined at an angle to the horizontal, that the drag coefficient is constant, that the gravitational acceleration is constant in the atmosphere, and that the scale height of the atmosphere is constant. Consideration is given to the effect of refraction arising from the temperature structure of the atmosphere on the shock wave generated by a vertically falling body.

DER RAUMSCHLITTEN. Georg Aumann, ZAMM, Nov.-Dec., 1956, pp. 433-436. In German. Deduction of the equations of motion for a force-free space sledge. A space sledge is defined as a rigid body moving in such a way that the absolute velocity of one of its points is either a) normal or b) parallel to a given direction within the body. It is shown that, in the case of spherical symmetry, there are - apart from the trivial periodic solutions - only solutions with periodic velocities in case a), while in case b) solutions with periodic velocities also exist.

STRUCTURES

SOME ASPECTS OF SAINT VENANT'S PRINCIPLE. G. Horvay. J. Mech. & Phys. Solids, Mar., 1957, pp. 77-94. 13 refs. Theoretical investigation to illustrate, for a number of important cases, the exponential decay with distance from the loaded edge which occurs when self-equilibrating tractions act on an edge of a rectangle. Results are also given for the half plane loaded by self-equilibrating edge tractions. In this case the stresses decay as integral powers of the distance. Includes an example showing the effect on the maximum stress of the rapidity of shear-traction variation.

CONSIDERATIONS SUR LA FATIGUE, SPECIALEMENT SUR L'ACCROISSEMENT DE LA DETERIORATION PAR DES EFFORTS ALTERNES D'AMPLITUDE VARIABLE. J. Schijve. Tech. et Sci. Aéronautiques, No. 6, 1956, pp. 299-306. 13 refs. In French. Study of the fatigue in aircraft structures, with special emphasis on the progress of damage produced by alternating stresses of variable amplitude. Results of the research performed at the Inst. Natl. de Rech. Aéron., Amsterdam, in order to verify Miner's hypothesis on the cumulative damage are presented.

SOME NEW DATA ON HIGH-SPEED IMPACT PHENOMENA. J. H. Huth, J. S. Thompson, and M. E. Van Valkenburg. (ASME Annual Meeting, New York, Nov. 25-30, 1956.) J. Appl. Mech., Mar., 1957, pp. 65-68. Summary of recent experiments aimed at evaluating the role of various physical parameters in high-speed impact phenomena. Includes an analysis of the phenomena and experimental results for steel, aluminum, brass, lead, magnesium, and a magnesium-lithium alloy.

YIELD LOADS OF SLABS WITH REINFORCED CUTOUTS. P. G. Hodge, Jr., and Nicholas Perrone. (ASME Annual Meeting, New York, Nov. 25-30, 1956.) J. Appl. Mech., Mar., 1957, pp. 85-92. 14 refs. ONR-sponsored development of a theoretical method for computing upper and lower bounds on the carrying capacity of a plane slab with a reinforced cutout. The slab is subjected to a uniaxial load which is either uniform or applied by means of a perfectly rigid clamp. Analysis assumes that the dimensions of the hub and slab are such that the stress distributions in the base slab may be characterized by plane stress, while the hub may be analyzed by general beam theory. Drucker, Greenberg, and Prager's limit-analysis theorems are used under the assumption that both the hub and slab are made of a perfectly plastic material satisfying the Tresca yield condition and the associated flow law. Results are compared numerically with experimental data obtained by Vasarhelyi and Hechtman.

THE EFFECT OF A CIRCULAR HOLE ON THE PURE TWIST OF AN INFINITE STRIP. Osamu Tamate. (ASME Annual Meeting, New York, Nov. 25-30, 1956.) J. Appl. Mech., Mar., 1957, pp. 115-121. 17 refs. Theoretical investigation using the method of perturbation to calculate the maximum deflections on the rim of the hole and the maximum stress couples in the strip, and to plot them against hole-diameter strip-width ratio and Poisson's ratio of the plate material. The strip is considered subjected to the limitation of the Poisson-Kirchhoff theory of bending of thin plates.

THE DIFFUSION OF LOAD FROM A STIFFENER INTO AN INFINITE ELASTIC SHEET. E.H. Brown. Proc. Royal Soc. (London), Ser. A, Mar. 12, 1957, pp. 296-310. Solutions of three different problems for the diffusion of load in an elastic sheet to which a semi-infinite elastic stiffener is continuously attached throughout its length. In the method employed, problems with mixed boundary conditions are reduced to second-order differential equations whose solutions can be found in series form. The first problem involves a load applied to the end of the stiffener, with its line of action along the stiffener and its reactions at infinity. In the other two problems the stiffener end is unloaded, but uniform tension is applied to the sheet at infinity, in one case parallel to the stiffener, in the other perpendicular to it.

NON-PROPAGATING CRACKS IN VEE-NOTCHED SPECIMENS SUBJECT TO FATIGUE LOADING. N. E. Frost. Aero. Quart., Feb., 1957, pp. 1-20. 18 refs. Results of reversed direct-stress and rotating bending-fatigue tests on specimens of alu-

minum alloy, nickel, chromium, steel, and mild steel. Diagrams are presented showing the relationship between the geometric concentration factor (K_t) and strength-reduction factor (K_f). It is found that nonpropagating cracks form in the roots of the sharper notches at or above some critical value of K_t - this critical value depending on the material. Below the critical value of K_t, cracks do not form unless the applied nominal stress exceeds that at the fatigue limit. A crack, once formed, however, continues to propagate until the specimen fails. Above the critical value of K_t, nonpropagating cracks form at nominal stresses less than the fatigue limit; the stress must increase to the latter value in order to propagate the crack. The critical value of K_t coincides with the maximum K_f value realized.

RESPONSE OF BEAMS AND PLATES TO RANDOM LOADS. A. C. Eringen. (ASME Annual Meeting, New York, Nov. 25-30, 1956.) J. Appl. Mech., Mar., 1957, pp. 46-52. 13 refs. Derivation of a solution for the problem of vibrating damped beams and plates under stochastic loading, by means of generalized harmonic analysis. The resulting equations give the cross-correlation functions for displacements, stresses, moments, etc., in terms of the cross-correlation function of external pressure. The probable number of times, per unit time, that the random displacements or stresses will exceed a given value is calculated using a method due to Rice. Includes detailed computations for the cases of simply supported and cantilever bars, and of clamped circular and simply supported rectangular plates.

ON THE STRESS DISTRIBUTION AT THE BASE OF A STATIONARY CRACK. M. L. Williams. (ASME Annual Meeting, New York, Nov. 25-30, 1956.) J. Appl. Mech., Mar., 1957, pp. 109-114. NACA-sponsored theoretical investigation for the case of a zero-angle notch or crack in an effort to verify the suggestion that a knowledge of the elastic-stress variation in the neighborhood of an angular corner of an infinite plate is of value in analyzing the stress distribution at the base of a V-notch. Includes remarks on the antisymmetric and the symmetric stress distribution, and on the circumferential distribution of distortion strain-energy density. Results indicate that, for the case of a symmetrical loading about the crack, the energy density is not a maximum along the direction of the crack but is one third higher at an angle $\pm \cos^{-1}(1/3)$; that, at the base of the crack in the direction of its prolongation, the principle stresses are equal, thus tending toward a state of (two-dimensional) hydrostatic tension; and that the distortion strain energy increases as the distance from the point of the crack increases.

Bars & Rods

LONGITUDINAL IMPACT OF A SEMI-INFINITE CIRCULAR ELASTIC BAR. Richard Skalak. (ASME Annual Meeting, New York, Nov. 25-30, 1956.) J. Appl. Mech., Mar., 1957, pp. 59-64. Theoretical investigation using the equations of motion of linear-elasticity theory and a method of double-integral transforms to analyze the impact of a semiinfinite elastic bar of circular cross section. The solution is evaluated by using approximations which are valid for large values of the time after the initial impact. The numerical results show a continuous dispersion of the wave front and an oscillation not found in the usual elementary-theory solutions.

Beams & Columns

SOME SIMPLE PROBLEMS OF FLEXURE. I. R. Mohan. ZAMM, Nov.-Dec., 1956, pp. 427-432. Solution of two flexure problems: a) that of a uniform beam having a horseshoe-shaped section bounded by two confocal ellipses and a portion of their minor axis and b) that of a uniform beam with a section bounded by a parabola and a straight line. The terminal load in each case is assumed to act symmetrically at right angles to the straight edge. A simple equation satisfied by the flexure function, which is slightly different from that obtained by Timoshenko, is deduced, and the final results are obtained as solutions of problems of the plane potential theory.

STRUCTURAL DAMPING OF A SIMPLE BUILT-UP BEAM WITH RIVETED JOINTS IN BENDING. T. H. H. Pian. (ASME Annual Meeting, New York, Nov. 25-30, 1956.) J. Appl. Mech., Mar., 1957, pp. 35-38. ONR-sponsored theoretical investigation of the structural damping in the bending of a simple built-up beam with thin reinforcing spar caps in which the rivets or screws prevent the sliding motion between the cap and the beam. An analytical expression of the energy loss per cycle of static loading is derived in terms of load, rivet stiffness, and joint tightness. Includes experimental measurements on a test beam to provide qualitative verification of the theory.

BEAMS OF UNIFORM STRENGTH SUBJECTED TO UNIFORMLY DISTRIBUTED LOADING. W. A. Gross and J. P. Li. (ASME Annual Meeting, New York, Nov. 25-30, 1956.) J. Appl. Mech., Mar., 1957, pp. 105-108. Determination of shapes, deflections, and weights for cantilever, simple, and fixed beams of uniform strength and appreciable weight subjected to uniformly distributed loadings. Explicit solutions are given for beams having rectangular cross sections and constant height, and solutions in integral form are provided for rectangular beams of constant width. The method described is also applicable to beams with constant height-to-width ratio as well as to beams with circular cross sections. Includes examples illustrating the large material savings that can be achieved over uniform cross-section beams.

THE PLASTIC BENDING OF AN ECCENTRICALLY LOADED COLUMN. W. E. Boyce. J. Aero. Sci., May, 1957, pp. 332-338, 362. 14 refs. ONR-sponsored analysis of an initially straight column subjected to eccentric axial end loads which increase from zero. The column is of sandwich construction, made of rigid, work-hardening material. A piecewise linear theory of plasticity is

used to analyze the lateral displacements which occur as the loads are slowly increased. In particular, a sudden stiffening effect shortly after the onset of plastic flow is noted and explained.

Cylinders & Shells

BUCKLING OF THIN-WALLED CIRCULAR CYLINDERS UNDER AXIAL COMPRESSION AND INTERNAL PRESSURE. Y. C. Fung and E. E. Sechler. J. Aero. Sci., May, 1957, pp. 351-356. Experimental investigation to check the validity, for the case where $\bar{p} \approx 2.0$, of Lo's theory that the critical buckling stress increases with increasing values of the dimensionless parameter $\bar{p}$ up to $\bar{p} \approx 0.169$, after which the buckling stress remains constant at a value equal to that given by the small-deflection theory. Results serve to verify this theory, with certain significant modifications in interpretation. A proposed design method is presented which is expected to give conservative values for the buckling stress of such cylinders. A series of photographs showing the variation of the buckling pattern with internal pressure is included in the treatment.

BUCKLING OF INITIALLY IMPERFECT CYLINDRICAL SHELLS SUBJECT TO TORSION. W. A. Nash. (ASME Annual Meeting, New York, Nov. 25-30, 1956.) J. Appl. Mech., Mar., 1957, pp. 125-130. 10 refs. OOR-sponsored derivation of an analytical solution based on large-deflection shell theory and using Donnell's fundamental equations together with the condition of stationary potential energy to determine all arbitrary deflection parameters. Boundary conditions corresponding to clamped-end shells and to shells having simply supported ends are considered. Load-deformation relations for various magnitudes of initial imperfection of the shell are determined for both boundary conditions, and values are presented for an imperfection factor based on existing experimental evidence for clamped-end shells.

ÜBER RANDWERTPROBLEME BEI HÄUTEN UND DÜNNEN SCHALEN IM MEMBRANSPANNUNGSZUSTAND. Erika Behlendorff. ZAMM, Nov.-Dec., 1956, pp. 399-413. In German. Theoretical investigation to define the three relations of compatibility which must be satisfied by the load distribution on the surface, and by the shearing stresses at the boundary, of a positive curved thin shell under tension in order for the moments to vanish. Analysis employs methods developed by Haack and Hellwig for the investigation of boundary problems in the theory of elliptical differential equations.

Elasticity & Plasticity

PLASTIC FLOW WITH AXIAL SYMMETRY, USING THE MISES FLOW CRITERION. D. H. Parsons. Proc. London Math. Soc., 3rd Ser., Oct., 1956, pp. 610-625. Analysis of equations governing the perfectly plastic flow of metal in three dimensions, with symmetry about an axis. The system is shown to be a singular one of the fifth order; any boundary problem for this system may be reduced to a corresponding boundary problem for an auxiliary, nonsingular system of the fourth order, having no real characteristics. It is also shown that the original problem admits no real characteristics, except possibly a curve in a meridian plane, along which the radial velocity is zero.

A MIXED BOUNDARY-VALUE PROBLEM OF ELASTICITY WITH PARABOLIC BOUNDARY. Gunadhar Paria. (ASME Annual Meeting, New York, Nov. 25-30, 1956.) J. Appl. Mech., Mar., 1957, pp. 122-124. Analysis of the problem of finding the stress distribution in a two-dimensional elastic body with parabolic boundary, subject to mixed boundary conditions, in order to reduce the problem to the solution of the nonhomogeneous Hilbert problem following the complex-variable method. The result is compared with that for a straight boundary.

STRESSES AND DISPLACEMENTS IN AN ELASTIC-PLASTIC WEDGE. P. M. Naghdi. (ASME Annual Meeting, New York, Nov. 25-30, 1956.) J. Appl. Mech., Mar., 1957, pp. 98-104. 14 refs. ONR-sponsored derivation of the complete solution for a wedge which has an included angle β and is subjected to a uniform normal pressure on one boundary. The wedge considered is elastic, perfectly plastic, and composed of an incompressible isotropic material in the plane-strain state, where the Prandtl-Reuss stress-strain relations are used in the plastic domain. The solution is valid in the range $0 < \beta < \pi/2$ - this limitation being due to the character of the initial yield which depends on the magnitude of β. Numerical results for stresses and displacements are given in the case in which $\beta = \pi/4$ for various positions of the elastic-plastic boundary.

THE PROPAGATION OF INFINITESIMAL PLANE WAVES IN ELASTIC-PLASTIC MATERIALS. J. W. Craggs. J. Mech. & Phys. Solids, Mar., 1957, pp. 115-124. 12 refs. Theoretical investigation with results indicating that plane waves of two types may exist - each involving both dilatation and shear strain. An equation for the velocities of such waves is given. Possible interactions between plastic (loading) waves and elastic (unloading) waves are discussed, and examples are presented which illustrate the treatment of such interactions.

A NEW METHOD FOR THE CONSTRUCTION OF HENCKY-PRANDTL NETS. E. G. Thomsen. (ASME Annual Meeting, New York, Nov. 25-30, 1956.) J. Appl. Mech., Mar., 1957, pp. 81-84. 12 refs. Rapid, graphical procedure which may be used for nets on both the physical plane and on the velocity plane or hodograph. Includes examples illustrating application.

Plates

THE LAUNCHING AND PROPAGATION OF ELASTIC WAVES IN PLATES. H. Pursey. Quart. J. Mech. & Appl. Math., Feb., 1957, pp. 45-62. 11 refs. Derivation of integral representations for the displacement of an arbitrary point in an isotro-

pic plate due to a stress distribution on the free surfaces which varies sinusoidally with time. It is shown that evaluation of the integrals leads to secular equations identical with those originally obtained by Lamb, and the solutions of these are investigated for symmetric and antisymmetric wave types in plates up to $8/\pi$ compressional wave lengths thick. New tables of solutions are provided for two principal waves, and graphical representations of the solutions corresponding to complementary waves are given.

ELASTIC-PLASTIC BENDING OF A BUILT-IN CIRCULAR PLATE UNDER A UNIFORMLY DISTRIBUTED LOAD. Bekir Tekinalp. J. Mech. & Phys. Solids, Mar., 1957, pp. 135-142. 18 refs. Analysis of the bending moments and deflections of a uniformly loaded and built-in circular plate made of incompressible elastic-plastic material obeying Tresca's yield condition and the associated flow rule. The treatment is simplified by assuming that any plate element is either entirely elastic or entirely plastic. This assumption is practically fulfilled for a sandwich plate; for a solid plate it represents a first approximation to the actual diagram of bending moment vs. curvature.

ON THE ANALOGY BETWEEN PLATES AND DISKS. W. Prager. Proc. Royal Soc. (London), Ser. A, Mar. 12, 1957, pp. 394-398. Extension of Southwell's analogy between elastic plates and discs of uniform thickness to inelastic plates and discs of varying thickness. The disc and plate are treated as two-dimensional continua that are contained in the x, y- plane of a system of rectangular Cartesian coordinates.

Testing

EXPERIMENTS FOR THE DETERMINATION OF TRANSIENT STRESS AND STRAIN DISTRIBUTIONS IN TWO-DIMENSIONAL PROBLEMS. A. J. Durelli and W. F. Riley. (ASME Annual Meeting, New York, Nov. 25-30, 1956.) J. Appl. Mech., Mar., 1957, pp. 69-76. Development of a photoelasticity method which avoids the difficulties usually encountered in using such a procedure by employing a specially constructed epoxy-resin material with a low modulus of elasticity and a correspondingly low wave-propagation velocity. It is shown that, in conjunction with this material, an 8-mm. Fastax camera is capable of recording precise fringe patterns. Preliminary studies are conducted to develop the method, using a circular disc under a radially applied impact load as the model. The deflection curves of a simply supported beam under central impact are then obtained and compared with curves theoretically predicted by St. Venant and Flamant. Includes analysis of the formation of the fringe pattern for various times after impact.

Thermal Stress

EXPRESSION OF INITIAL STRESSES BASED ON GREEN'S FUNCTIONS. Toshio Mura and Nobuo Kinoshita. J. Japan Soc. Aero. Eng., Jan., 1957, pp. 7-10. Analysis to determine at what point the induced thermal stress source becomes maximum and what is its maximum value. When the internal stress source is given, the initial stress is expressed, using Green's functions, by the incompatibility and the dislocation of the internal stress source.

THERMODYNAMICS

Combustion

COMBUSTION AND DETONATION IN GASES. B. Greifer, J. C. Cooper, F. C. Gibson, and C. M. Mason. J. Appl. Phys., Mar., 1957, pp. 289-294. 18 refs. OOR-supported investigation to observe experimentally the mechanism of initiation and structure of detonation waves. Streak schlieren photographs of hydrogen/oxygen and carbon-monoxide/oxygen explosives are made in a rectangular shock tube using precision optics and a rotating mirror camera. The photographs show that compression waves generated during the early stages of propagation of the explosion soon steepen into a shock wave which travels ahead of the combustion wave. This combination of shock and combustion wave is charateristic of a nonsteady detonation state in the moments before stable detonation is initiated. The distance between the two waves narrows as the explosion progresses down the tube due to continued formation of new combustion centers ahead of the combustion waves by means of auto-ignition. Eventually the combustion wave overtakes the shock wave and supplies it directly with energy from the chemical reaction. At this moment stable detonation is initiated.

A CONTRIBUTION TO FLAME THEORY. Appendix - VISCOSITY. G. Klein. Philos. Trans. Royal Soc. (London), Ser. A, Feb., 1957, pp. 390-415. Theoretical investigation of a one-dimensional flame model whose equations are written concisely by means of suitable dimensionless quantities, with temperature chosen as an independent variable. The assumption that the flame velocity is unknown leads to the occurrence of a related unknown constant, determined by the boundary conditions, in nonlinear differential equations which are solved simultaneously with the diffusion equations. The equations of the simplest flame of reaction are discussed in detail and a procedure for their solution is derived and generalized. Analysis includes review of the equations of a reacting gas mixture and their flame applications - taking into account ordinary diffusion in terms of binary diffusion coefficients but neglecting the diffusion thermoeffect and radiation - and results of computations relating to special ideal flames which separately bear some features of real ones.

VTOL & STOL

FLIGHT TESTS OF A MODEL OF A HIGH-WING TRANSPORT VERTICAL-TAKE-OFF AIRPLANE WITH TILTING WING AND PROPELLERS AND WITH JET CONTROLS AT THE REAR OF THE FUSELAGE FOR PITCH AND YAW CONTROL. P. M. Lovell, Jr., and L. P. Parlett. US, NACA

TN 3912, Mar., 1957. 28 pp. Investigation of the stability and control of a high-wing transport model. The model experiences a nose-up change in pitch trim at low speeds in the transition from hovering to forward flight. Because of this trim change, the most rearward center-of-gravity location at which the model can be flown is limited to 8% mean aerodynamic chord rearward of the wing pivot point, with the wing flaps deflected, and 6% mean aerodynamic chord rearward of the wing point, with the flaps undeflected. When the center of gravity is located rearward of these points, the model experiences a nose-up pitching divergence. The lateral stability and control characteristics are generally satisfactory, and the jet controls provide good pitch and yaw control throughout the entire speed range.

SOME AEROELASTIC PROBLEMS OF TILT-WING VTOL AIRCRAFT. Appendix A - WING ANALYSIS METHOD. Appendix B - SUMMARY OF WING - FUSELAGE ATTACHMENT MATRICES AND END CONDITIONS. Appendix C - DERIVATION OF EQUIVALENT MASS AND MASS MOMENT OF INERTIA EXPRESSIONS. R. G. Loewy and R. T. Yntema. IAS 25th Annual Meeting, New York, Jan. 28-31, 1957, Preprint 727. 28 pp. Members, $0.85; nonmembers, $1.30. Analysis of problems concerned with special wing-root attachments, wing center-section discontinuities, rotor-blade twist, and root fixity and flexibility. The significance of changes in wing-tilt position, rotor-operating speed, and rotor-blade pitch setting, which accompany changes from hovering to forward flight, are also considered. The particular problems treated include rotor-blade resonance, wing vibration, coupled wing-rotor vibration, mechanical instability involving wing-rotor coupling, wing flutter, wing divergence, and aileron reversal. The Holzer matrix method is applied to the solutions of all problems tested, with the exception of flutter.

WATER-BORNE AIRCRAFT

THE FULL SCALE AIR DRAG OF SOME FLYING BOAT SEAPLANES. A. G. Smith. Gt. Brit., MAEE Rep. F/Res/265, Feb., 1956. 83 pp. 24 refs. Comparison of recovered drag and lift for the Sunderland, Solent, Shetland, Sealand, Saro E6/44, and Princess flying boats, which all have hulls of fairly orthodox length/beam and fineness ratios but with different degrees of aerodynamic fairing. The results show a pronounced increase in efficiency of aerodynamic fairing and a reduction of overall drag coefficient with successive designs, culminating in the Princess. The drag coefficient and profile drag show progressive decreases from the order of 0.033 to 0.018 and from 1.5 lb. to 0.33 lb. per 100 lb. of all-up weight, respectively. This drag reduction is caused by improvement in hull design, reduction of drag with change of propulsion unit from propeller reciprocation to propeller turbine and turbine jet, and also with increase in size.

A THEORETICAL AND EXPERIMENTAL STUDY OF PLANING SURFACES INCLUDING EFFECTS OF CROSS SECTION AND PLAN FORM. C. L. Shuford, Jr. US, NACA TN 3939, Mar., 1957. 126 pp. 36 refs. Development of a revised rectangular-flat-plate theory which bases the aerodynamic suction effects on the total lift, rather than solely on the linear component. The theory is extended to include triangular flat plates planing with base forward and V-shaped prismatic surfaces having a constant angle of dead rise, horizontal chine flare, or vertical chine strips. A method is also presented for estimating the center of pressure for surfaces having either a rectangular or triangular plan form. The calculated results are correlated only with the experimental data considered pure planing, but a method is also given for estimating the effects of buoyancy for conditions not considered pure planing.

CALCULATION OF HYDROFOIL SECTIONS FOR PRESCRIBED PRESSURE DISTRIBUTIONS. B. R. Parkin and G. H. Peebles. SNAME Tech. & Res. Bul. 1-17, Dec., 1956. 55 pp. 10 refs. Method for designing hydrofoils or airfoils using well-known theories of incompressible, inviscid, steady flow and conformal transformations. A profile design is begun by tentatively specifying the pressure distribution desired at selected angles of attack. These specifications which usually conflict with each other are reconciled in order to correspond to an existing but unknown profile. The coordinates of the section are then accurately and rapidly calculated.

WIND TUNNELS & RESEARCH FACILITIES

INVESTIGATION OF TRANSONIC TEST SECTION WITH PERFORATED WALLS. Ryuma Kawamura and Haruo Saito. J. Japan Soc. Aero. Eng., Jan., 1957, pp. 1-6. Test results giving the effects of Reynolds Number, the diameter of holes in the perforated walls, the blockage due to a model, the opening ratio of the perforated walls, and the length of the test section on the mass-flow removal through the walls. This mass-flow removal is necessary to obtain transonic Mach Numbers in the test section. The investigation is made at comparatively high Reynolds Numbers by blowing down compressed air through a model tunnel with a 5 x 4 cm. test section. The results indicate that perforated walls of opening ratio larger than 30% increase mass-flow removal, and that the larger the test section the greater is the suction required.

CHRONOGRAPH TIMES SUPERSONIC MODELS. W. J. Kerwin. Electronics, Apr. 1, 1957, pp. 152-155. Development of a circular-sweep, five radius oscilloscope display which provides vernier readings for four counter circuits used to measure drag on small free-flight models in supersonic wind-tunnel tests. Accuracy of the 1.6 mc. counter is increased to ± 0.025 microsec. by determining time lapse between start pulse and first count, and between last count and stop pulse. Discussion includes principles of operation and description of the overall circuit, oscillator, phase-shift network, and output stage.

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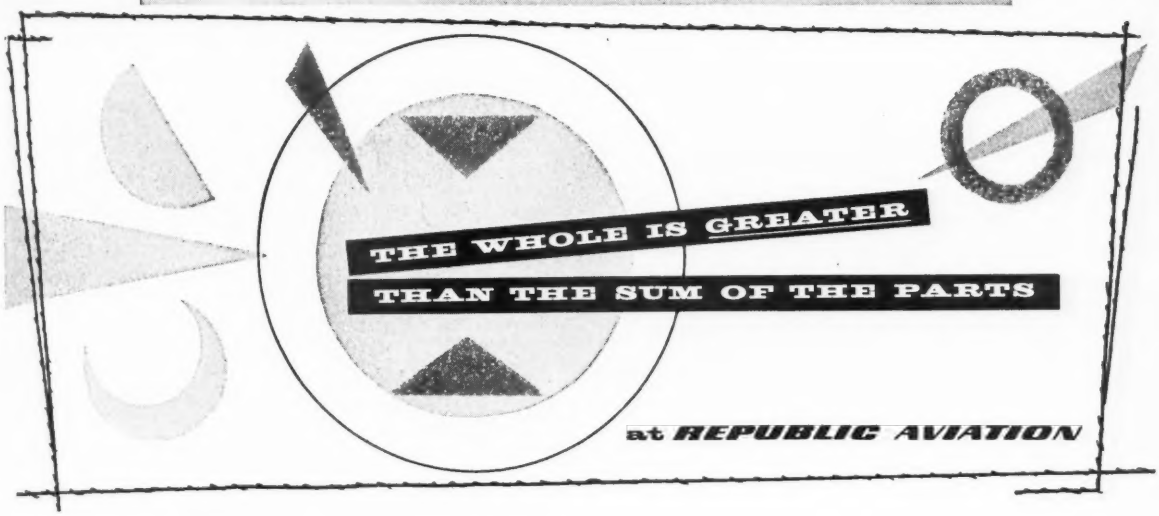

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The Hard Eloxation Process. L. Bosdorf and A. Beyer. (*Aluminium*, No. 7/8, 1955, pp. 321–327.) *Gt. Brit., MOS TIL/T4608*, Sept., 1956. 12 pp. 15 refs. Translation. Description of the eloxal process for hardening the surface of aluminum and of the properties of alloys so treated.

High Temperature Magnesium for Supersonic Aircraft. *Auto. Ind.*, Feb. 15, 1957, pp. 66–69. Survey of magnesium-thorium alloys giving mechanical properties for elevated temperatures.

Magnesium-Thorium Alloys; An Evaluation of Their Properties and Characteristics. Donald Mathews. *Mag. of Magnesium*, Feb., 1957, pp. 4–7.

The Hardness of Wrought Titanium. A. R. G. Brown and P. M. R. Gates. *Gt. Brit., RAE TN Met.243*, July, 1956. 14 pp. Comparison for hardness of forged, rolled, and swaged bars of pure titanium annealed for various times at 550°, 650°, 700°, and 750°C.

Nonmetallic Materials

Elastomeric Materials. Martin H. Brewer. (*IAS 25th Annual Meeting, New York, Jan. 28–31, 1957.*) *ARDC News Serv. Rel. 4-57*, Jan. 29, 1957. 12 pp. Discussion of elastomers and their application to new aircraft and missiles. The demands of these systems embody resistance to high temperatures and degradation by new synthetic fuels, resistance to erosion during high-speed flight through rainfall, and the ability to function and survive within a nuclear environment.

The Influence of Test Conditions on the Measured Mechanical Strength of Glass. H. Schönborn. (*Silikattechnik*, No. 4, 1953, pp. 531–535.) *Gt. Brit., RAE Lib. Transl. 607*, Nov., 1956. 14 pp. 27 refs.

Considerations on the Definition and Determination of Adhesion. M. N. M. Boers. (*Verfkroniek*, No. 12, 1955, pp. 333–335.) *Gt. Brit., MOS TIL/T4714*, Nov., 1956, 7 pp. Translation.

The Extensibility of Nylon and Terylene Fabrics Under Cyclic Stress. J. E. Swallow. *Gt. Brit., RAE TN Chem.1289*, Nov., 1956. 17 pp. Experimental investigation with results indicating that Terylene has a greater strain hysteresis than nylon and its subsequent recovery is slower, and that porosity changes in parachute fabrics under cyclic stressing are closely related to the extension under load and to the residual deformation after removal of stress.

Accelerated Fatigue of Plastics. Lawrence S. Lazar. *ASTM Bul.*, Feb., 1957, pp. 67–71. Study of the Prot accelerated loading method for determining fatigue limits of plastics under rotating and nonrotating fatigue conditions.

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The Relative Reactivities of Bifunctional Monomers. V—Swelling Studies of Polymers of Various Allylic Methacrylates. G. M. Bristow. *Gt. Brit., RAE TN Chem.1286*, Nov., 1956. 31 pp. Measurements in toluene to determine degrees of cross linking in several prepared cross-linked polymers.

Selecting Plastics Laminates for Industrial Use. Malcolm W. Riley. *Materials & Methods*, Feb., 1957, pp. 121–140. Discussion of reinforced thermosetting laminates, glass-reinforced polyester laminates, and vulcanized fiber in terms of properties, standards and grades, combination laminates, and fabrication characteristics.

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A Study of the "Toss Factor" in the Impact Testing of Cermets by the Izod Pendulum Test. H. B. Probst and Howard T. McHenry. *U.S., NACA TN 3931*, Feb., 1957. 13 pp. 12 refs. Experimental investigation of the energies involved in the Izod pendulum test and the two components—recovery of stored elastic energy and kinetic energy contributed directly from the apparatus—contributing to the total "toss energy." A method is described for determining the kinetic energy imparted to the free half of a specimen by the apparatus.

High - Resolution Autoradiography. George C. Towe, Henry J. Gomberg, and J. W. Freeman. *U.S., NACA Rep. 1243*, 1955. 52 pp. 101 refs. Supt. of Doc., Wash, $0.45. Investigation to adapt high-resolution wet-process autoradiographic methods, developed in other fields, to the study of metal structures.

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The Down-Hill Method of Solving a Polynomial Equation. James A. Ward. *USAF HADC TN 57-2 [AD 113032]*, 1957. Description of a numerical procedure for solving $f(z) = 0$ for any desired accuracy. It is shown that this technique, which works equally well for determining real or imaginary roots of a polynomial equation with real coefficients and which will always converge, can be applied using a digital computer.

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A Matrix Method for the Numerical Solution of Linear Differential Equations with Variable Coefficients. E. A. Winn. *J. RAeS*, Feb., 1957, pp. 133, 134. Derivation of a procedure which employs finite difference techniques and which is, at least in principle, capable of extension to any order of accuracy.

Differential Equations Involving a Parametric Function. R. H. Cameron. *U. Minn. AFOSR TN 56-487*, Oct., 1956. 11 pp.

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The Effect of a Tangential Force on the Contact of Metallic Bodies. J. S. Courtney-Pratt and E. Eisner. *Proc. Royal Soc. (London), Ser. A.*, Jan. 29, 1957, pp. 529–550. 36 refs. Investigation of the tangential movement of two bodies relative to each other and of the size of the area of contact between them, when they are first loaded normally and then subjected to tangential forces too small to cause sliding.

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Ballooning. I—Notes on the History of Ballooning. C. H. Gibbs-Smith. **II—The Use of Balloons in Meteorology.** D. N. Harrison. **III—Constant-Level Ballooning.** C. S. Durst. *J. Inst. Navigation*, Jan., 1957, pp. 63–74; Discussion, pp. 74–77.

An Approach to Quantitative Precipitation Forecasting. M. A. Estoque. *J. Meteorology*, Feb., 1957, pp. 50–54. USAF-sponsored description of a quantitative method for predicting precipitation due to large-scale vertical motion.

Investigations Relating to Cirrus Cloud. D. G. James. *Meteorological Mag.*, Jan. 1957, pp. 1–12. Analysis of some 200 reports on the presence or absence of cirrus clouds, giving statistical relationships between occurrence and nonoccurrence.

Measurement of Infra-Red Radiation Flux in the Free Atmosphere. H. G. Muller and W. Pohl. (*Bayerische Akad. Wissenschaften, Sitzungsber.*, 1955, pp. 303–307.) *Gt. Brit., RAE Lib. Transl. 620*, Dec., 1956. 4 pp. 11 refs. Experimental investigation using modified Radiosonde equipment.

Measurements of Cloud Drop-Size Distributions. Ralph G. Eldridge. *J. Meteorology*, Feb., 1957, pp. 55–59. 20 refs. USAF-sponsored method of analyzing infrared transmittance of a natural

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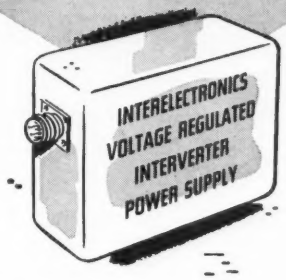

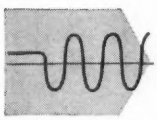

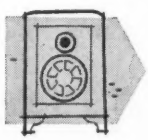

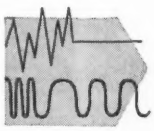

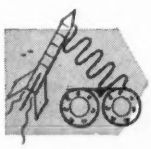

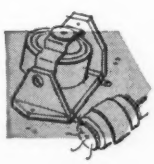

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cloud from which the drop-size distribution can be inferred. This technique is used to measure and analyze ten cloud situations on Mt. Washington.

Graphical Integrations of a Two-Level Model. M. A. Estoque. *J. Meteorology*, Feb., 1957, pp. 38–42. USAF-sponsored development of a prediction model to produce 24-hour 1,000- and 500-millibar forecasts.

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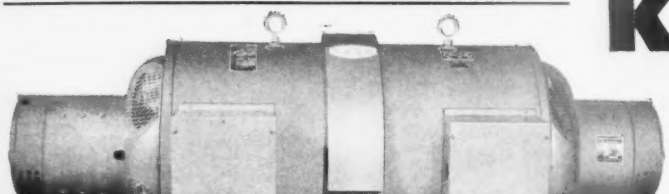
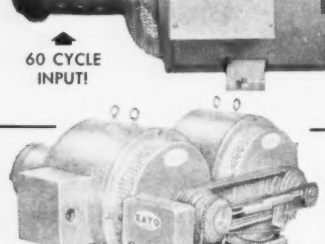


KATO MOTOR GENERATOR SETS are now available in frequencies, speeds, and sizes to meet every specialized use . . . lighting, operation of high cycle tools, smaller lightweight 400 cps motors and for testing components such as transfers, filters, condensers, chokes and other electronic equipment. Finest quality materials and workmanship.

AUTOMATIC ADJUSTMENT MODEL 45 EPOT

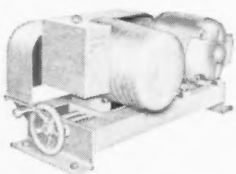


Fully automatic variable frequency motor generator set adjusts 360 to 400 CPS.

Generator mounted controls include reset buttons, limit switch. Motor and Generator remain stationary. Vari-drive pulley adjustment controlled by small motor.

VARIABLE OR FIXED FREQUENCIES RANGING FROM 25 TO 1200 CYCLES. 60 CYCLE LINE UP TO 500 KVA

MANUAL ADJUSTMENT MODEL 28XA08



Easily adjusted by simple hand wheel, controlling variable pitch pulley V-belt arrangement. This motor generator set gives 45 to 60 CPS output. Unit holds speed accurately. Frequency meter on generator panel indicates output. Single phase generator speed varies from 1350 to 1950 RPM.

CONTROL PANELS

Synchronous motor starter and generator controls including magnetic amplifier voltage regulator in cabinet.

REMOTE CONTROL

Remote control frequency adjustment varies speed from 1080 to 1320 RPM., thus varying frequency. Bench mock-up test stations may be located anywhere.

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Infrared for Missile Guidance, Fire Control, Thermal Mapping. James Holahan. *Av. Age*, Mar., 1957, pp. 90, 91–97 ff. Discussion explaining how infrared works and what it can accomplish. Includes chart of properties of infrared transmitting materials.

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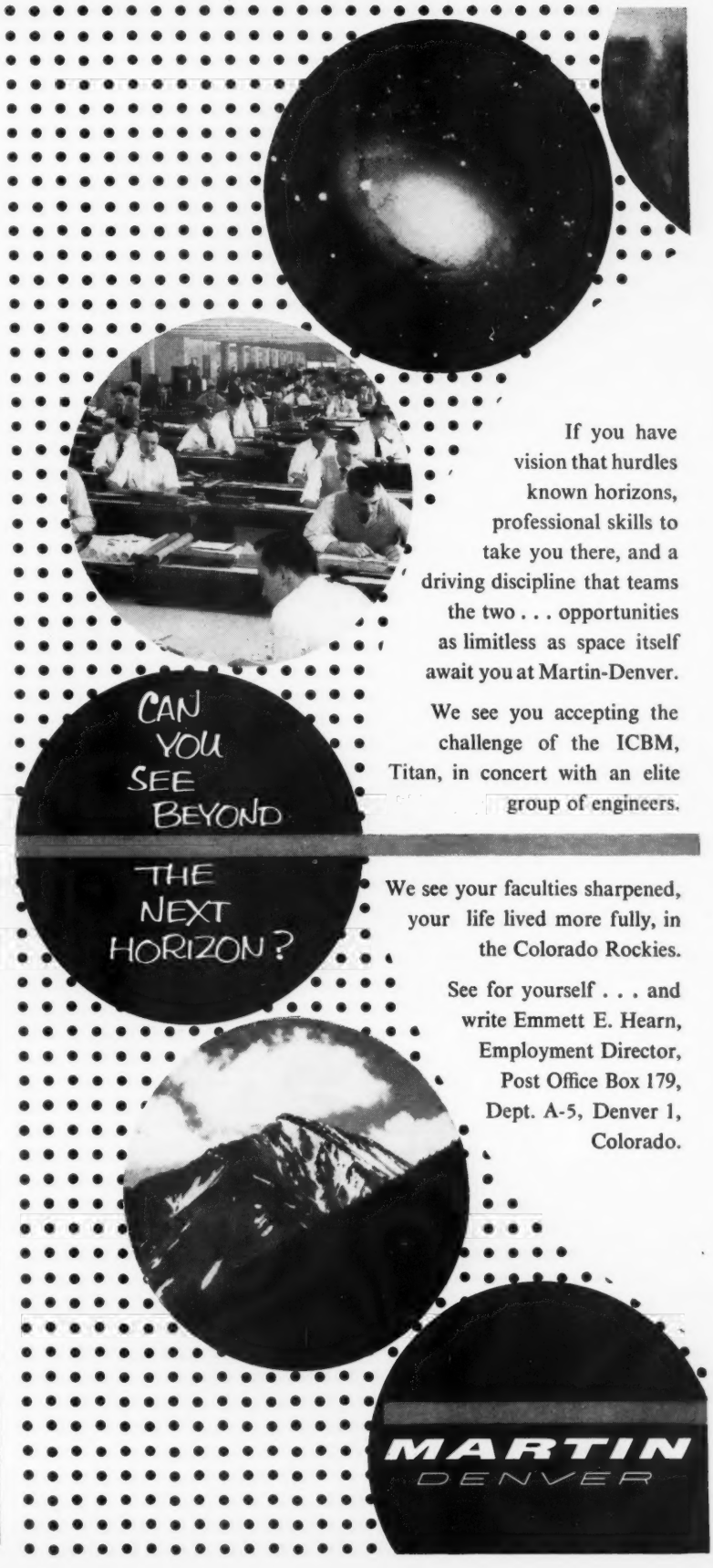
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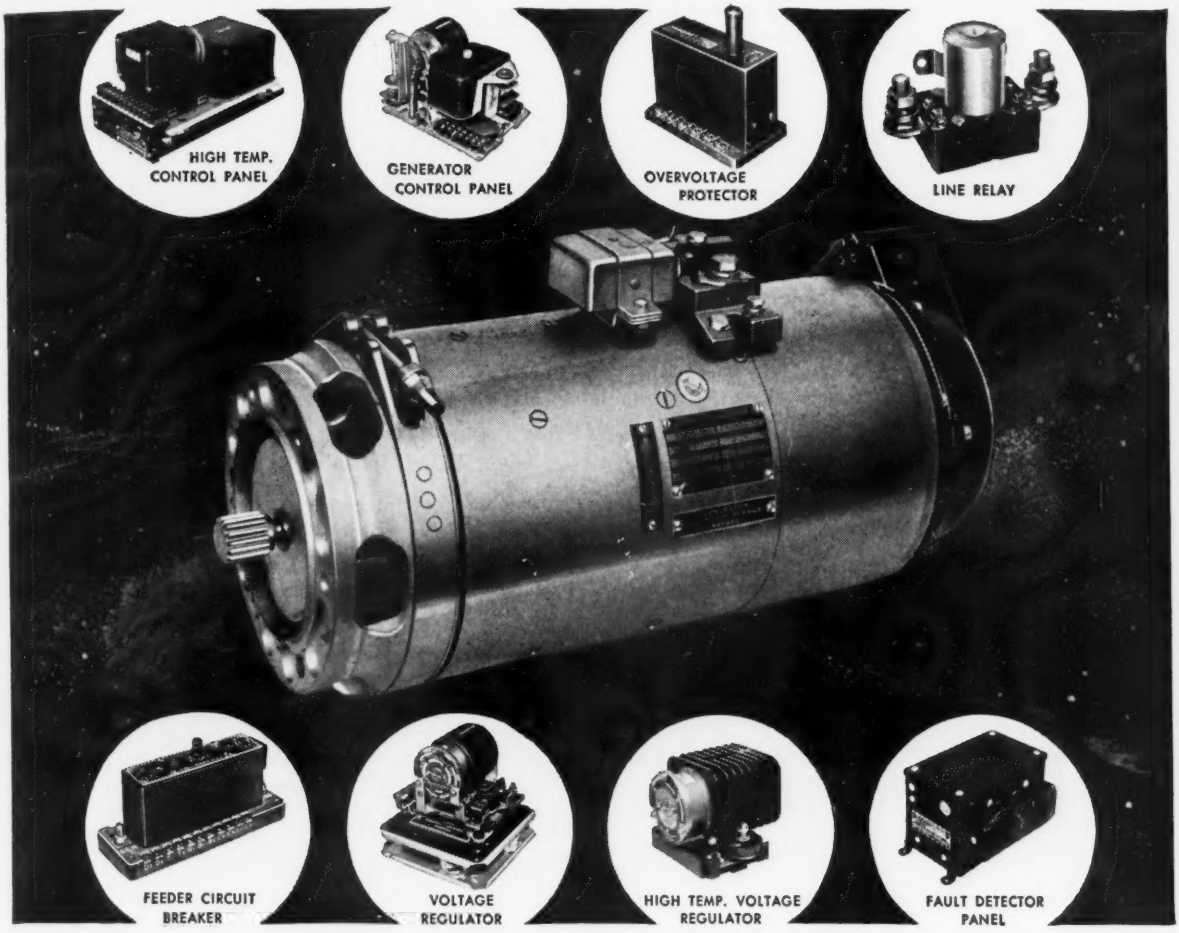

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30E16	100	2500–4500	50,000	40	52B6588
30B33*	100	4700–8000	35,000	28	MIL-S-9181
30E07	200	3350–8000	50,000	45	AN-3632
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30E02	300	3450–8500	25,000†	64	—
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Some Problems of High-Vacuum Metallurgy. W. Scheibe. (*Metall*, Berlin, No. 19–20, 1953, pp. 751–754.) *Gt. Brit., MOS TIL/T4603*, Sept., 1956. 6 pp. Translation. Discussion of such problems as vapor pressure, gas sensitivity, and methods for melting without crucibles.

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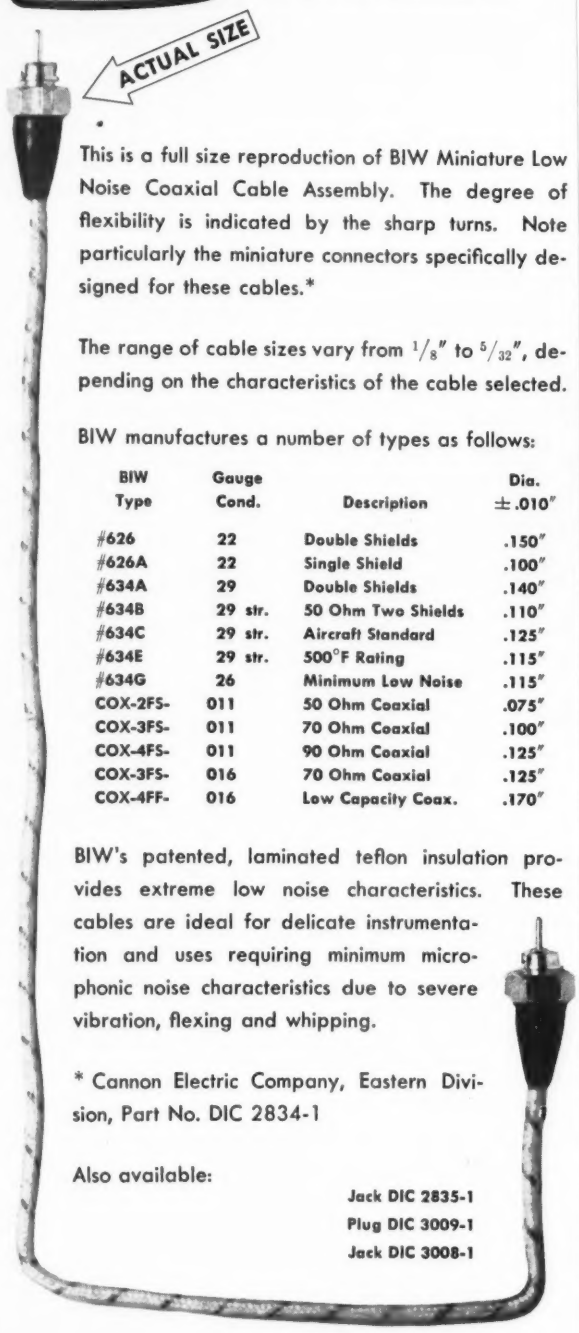

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#626A	22	Single Shield	.100"
#634A	29	Double Shields	.140"
#634B	29 str.	50 Ohm Two Shields	.110"
#634C	29 str.	Aircraft Standard	.125"
#634E	29 str.	500°F Rating	.115"
#634G	26	Minimum Low Noise	.115"
COX-2FS-	011	50 Ohm Coaxial	.075"
COX-3FS-	011	70 Ohm Coaxial	.100"
COX-4FS-	011	90 Ohm Coaxial	.125"
COX-3FS-	016	70 Ohm Coaxial	.125"
COX-4FF-	016	Low Capacity Coax.	.170"

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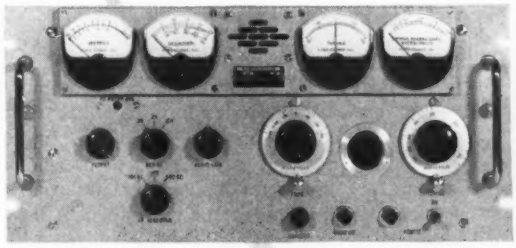

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Spectrum Display Output	Provisions for connecting a 30 MC Spectrum Display Unit (NEMS-CLARKE, Inc., SDU-200)
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Aeronautical Reviews — BOOKS

AERODYNAMICS

Solution of Problems in Aerodynamics. S. A. Urry. London, Sir Isaac Pitman & Sons, Ltd., 1957. 382 pp., diagrs., tables. 32*s*. 6*d*.

Designed for British students who are preparing for an examination in aerodynamics or the mechanics of flight, this book, one of Pitman's Engineering Degree Series, contains 400 problems, each of which is preceded by a summary of formulas essential to its solution. Fully half of these problems are worked out in detail, and answers are provided for the remainder. The use of complex numbers, partial differentiation, and other advanced mathematics has been avoided, and the topics themselves are arranged in order of increasing difficulty. Mr. Urry, who is Lecturer in Mechanical Engineering, Wandsworth Technical College, closes his text with a classified bibliography relating to the principles of flight.

Contents: (1) Properties of Fluids. (2) Properties of the Atmosphere. (3) Bernoulli's Equation. (4) Dimensional Analysis and Dynamic Similarity. (5) Lift and Drag Characteristics of Aerofoils. (6) Straight and Level Flight. (7) Climbing, Gliding and Turning Flight. (8) Aerofoil Pressure Distribution and Control-Surface Characteristics. (9) Equilibrium and Stability. (10) Propeller Theory and Performance. (11) The Stream Function. (12) Circulation, Vorticity and Lift. (13) Three-Dimensional Aerofoils. (14) Viscous Flow and Compressible Flow.

AIRCRAFT

The World's Fighting Planes. William Green and Gerald Pollinger. 2nd Rev. Ed. Garden City, N.Y., Hanover House, 1956. 240 pp., illus., diagrs. $3.50.

This compact reference book of British origin contains nearly 500 photographs and three-view identification silhouettes of all operational combat aircraft known to be in existence and supplies data on their specifications, history, performance, and armament. Training and transport aircraft and helicopters are also included since many of these are readily convertible into combat aircraft. Each of 21 countries' nationally produced military aircraft are dealt with in turn in alphabetical order of their manufacturers' names with the sole exception of the U.S.S.R., whose aircraft are listed in the alphabetical order of the code names applied to them by the Western forces.

Aeroplanes and Aero-Engines. J. H. Clark, J. Crawley, B. A. J. Hatton, R. J. Way, and R. Wood. London, Temple Press Ltd.; New York, Philosophical Library, 1956. 12 fold. charts. $6.00.

The latest edition of this series contains 24 cutaway drawings that have appeared in *The Aeroplane* during the past 3 years. A variety of British civil and military machines are featured, ranging from the largest air liners and military transports to the latest general purpose and crop-dusting aircraft. Two helicopters are included—the Bristol Type 171 MK.4 Sycamore and the Westland Whirlwind. An extensive descriptive key supports each drawing, and there are ten illustrations of power plants currently in service or undergoing test.

British Civil Airworthiness Requirements, Section A, General Information and Procedure, Issue No. 4. London, Air Registration Board, February 1, 1957. 64 pp., diagrs. 5*s*.

AVIATION MEDICINE

Aviation Medicine; An Annotated Bibliography, 1952 Literature. Arnold J. Jacobius and Madeleine J. Wilkins. Technical Information Division, Library of Congress. Washington, Office of Technical Services, November, 1956. 204 pp. $4.00 (PB-121543).

This is the first annual cumulation of a literature project initiated by the Naval Bureau of Medicine and Surgery and the Office of Naval Research. Since Hoff and Fulton's *Bibliography of Aviation Medicine Supplement* appeared in 1944, there has been no adequate compilation on the subject, and the present bibliography is designed partly to bridge this gap. Present plans call for starting with the year 1951 and continuing onwards. If it becomes possible, an attempt may be made to bridge the gap between 1944 and 1951.

The journals, books, and reports cited include only literature of direct applicability to aviation-medical research. The abstracts supply concise data concerning purpose, scope, experimental methods employed, and conclusions reached by the author. Since the bibliography lists references alphabetically by author, a subject index is supplied to facilitate searching.

Symposium on Air Force Human Engineering, Personnel, and Training Research. Edited by Glen Finch and Frank Cameron. Held under the Auspices of the Division of Anthropology and Psychology, National Academy of Sciences—National Research Council, at the Request of Headquarters, ARDC, USAF, November 14–16, 1955, Washington. (USAF ARDC Technical Report No. 56-8.) Baltimore, ARDC, USAF, 1956. 316 pp., illus., diagrs., tables.

Partial Contents: Dark Adaptation as a Function of the Intensity and Distribution of Light Across the Preadaptation Field, Charles A. Baker, Anthony Debons, and Dominic F. Morris. Experimental Procedures for Increasing Reinforced Practice in Training Air Force Mechanics for an Electronic System, Leslie J. Briggs and Guy G. Besnard. The Background and Implications of the Systems Research Laboratory Studies, Robert L. Chapman and John L. Kennedy. The Effects of Sleep Deprivation on Performance of a Complex Mental Task, Walter D. Chiles. The Perception of Direction as a Function of Binaural Temporal and Amplitude Disparity, R. J. Christman. The Problem of Optimum Group Assembly, Paul S. Dwyer. The Use of Statistical Decision Functions in Making Practical Decisions, Ward Edwards. Application of Auto-Correlation and Cross-Correlation Analysis to the Study of Tracking Behavior, Paul M. Fitts, William F. Bennett, and Harry P. Bahrick. Prediction of Pilot Training Performance—Aptitude Tests and Early Flying Proficiency Evaluations, Eli S. Flyer and Abraham Carp. Evaluation of a K-System Trouble-Shooting Trainer, Robert Stanton French. A Descriptive Study of Electronic Trouble Shooting, Richard W. Highland, Slater E. Newman, and Harry S. Waller. Predicting Speech Communication in Noise, J. M. Pickett. Shape Discrimination as a Function of Area and Luminance, Raymond Sabeh. Two Studies in Evaluation of Maintenance Training Devices, Robert A. Swanson, A. A. Lumsdaine, and Lewis E. Aukes. The Effect of Positive Acceleration (G) on the Relation Between Illumination and Dial Reading, William J. White and Mitchell B. Riley. Subject Index. Author Index.

For Information on IAS Library Services, see page 155

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CIVIL AVIATION

1960–1965–1970 Civil Aviation and Federal Airways Forecasts. Herbert J. Guth, Stafford Kernan, Hugh J. May, and Bion Williams. U.S., Civil Aeronautics Administration, Program Planning Office. Washington, Superintendent of Documents, December, 1956. 70 pp., charts, tables. $0.75.

This study contains, in addition to a treatment of aviation and the national economy, forecasts of domestic air-line passenger and cargo volume, United States international air-line traffic, general aviation flying activity, and certain key Federal Airways activities—among them air carrier and itinerant aircraft operations, fix postings, and instrument approaches.

Statistical Handbook of Civil Aviation, 1956. U.S. Civil Aeronautics Administration. Washington, Superintendent of Documents, 1956. 131 pp., diagrs., tables. $0.55.

A summary of official statistical data on the status of civil aviation in the United States through December, 1955.

DICTIONARIES

Russian-English Glossary of Nuclear Physics and Engineering. I. Emin, Editor. New York, Consultants Bureau, Inc., 1957. 195 pp. $10.

This interim glossary to a *Russian-English Physics Dictionary* scheduled for publication during 1959 contains approximately 10,000 Russian scientific and technical terms, ordinary expressions, and idioms which have special meaning in the various fields of physics. It includes all the terms incorporated in the *Russian-English Dictionary of Nuclear Physics and Engineering*, by N. N. Ershov, Y. V. Semenov, and A. I. Cherny, which was published by the Institute of Scientific Information of the Academy of Sciences of the USSR. Some 2,000 additional terms taken from recent issues of Soviet journals—such as the *Journal of Experimental and Theoretical Physics*, the *Journal of Technical Physics*, the *Journal of Atomic Energy*, and the *Physics Section* of the *Proceedings of the USSR Academy of Sciences*—have been added to round out this tool for researchers and technicians whose work requires that they keep abreast of the most recent Soviet research in the fields.

Jets, Wakes, and Cavities

By GARRETT BIRKHOFF, *Harvard University* and E. H. ZARANTONELLO, *Universidad de Cuyo, Mendoza, Argentina*

March 1957, 353 pp., illus., $10.00

The present volume reports systematically the most important findings of nearly 100 years of ingenious research in the fascinating and complex field of jets, wakes, and cavities.

CONTENTS: Background and Prospectus. Circular Sector Hodographs. Simple Flows Past Wedges. General Theory. Multiple Plates. Curved Obstacles. Existence and Uniqueness. Compressibility and Gravity. Effective Computation. Axially Symmetric Flows. Unsteady Potential Flows. Steady Viscous Wakes and Jets. Periodic Wakes. Turbulent Wakes and Jets. Miscellaneous Experimental Facts. BIBLIOGRAPHY-SUBJECT INDEX.

Gas Dynamics

By KLAUS OSWATITSCH, *Institute for Theoretical Gas Dynamics, Aachen*

English version by G. KUERTI, *Case Institute of Technology, Cleveland*

Dec. 1956, 610 pp., illus., $12.00

This book gives a clear and intuitively meaningful discussion of the physical and technical problems of dynamics. The encyclopedic treatment of the subject offers many new cross-relations which lead to a unifying view of the field.

Author and translator have cooperated closely to bring the English version of this volume up-to-date.

CONTENTS: Thermodynamics. Steady One-Dimensional Flow. Unsteady One-Dimensional Flow. General Equations and Theorems. Application of the Integral Theorems in Particular Cases. General Equations and Particular Exact Solutions for Steady Inviscid Flow. Steady, Inviscid Plane and Axisymmetric Subsonic Flow. Steady Inviscid Plane and Axisymmetric Supersonic Flow. Steady Inviscid Transonic Flow. Steady and Unsteady Three-Dimensional Flow Problems. The Influences of Viscosity. Survey of Experimental Techniques; Flow Analogies. AUTHOR INDEX-SUBJECT INDEX.

Fatigue in Aircraft Structures

Proceedings of an International Conference held at Columbia University

Edited by ALFRED M. FREUDENTHAL, *Columbia University*

Dec. 1956, 456 pp., illus., $12.00

CONTENTS:

Part I. Physical Theories of Fatigue
Part II. Prediction of Fatigue Life and Fatigue Strength
Part III. Prevention of Fatigue Failure

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ELECTRONICS

Reference Data for Radio Engineers. 4th Ed. New York, International Telephone and Telegraph Corporation, 1957. 1,121 pp., diagrs., tables. $6.00.

Expanded to nearly four times the size of the previous edition, which appeared in 1949, this ready reference is a single-volume compilation of data often needed in radio and electronic engineering. Having proved its usefulness to practicing engineers, the book has been accepted as a text in over 200 universities, technical schools, and colleges in the United States. The selection and preparation of the material was performed by a large group of practical engineers, each contributing in his particular field of specialization.

Contents: Frequency Data. Units, Constants, and Conversion Factors. Properties of Materials. Components. Fundamentals of Networks. Filters, Image-Parameter Design. Filters, Modern-Network-Theory Design. Filters, Simple Bandpass Design. Attenuators. Bridges and Impedance Measurements. Iron-Core Transformers and Reactors. Rectifiers and Filters. Magnetic Amplifiers. Feedback Control Systems. Electron Tubes. Electron-Tube Circuits. Semiconductors and Transistors. Transistor Circuits. Modulation. Transmission Lines. Waveguides and Resonators. Scattering Matrixes. Antennas. Radio-Wave Propagation. Radio Noise and Interference. Broadcasting. Radar Fundamentals. Wire Transmission. Electroacoustics. Digital Computers. Nuclear Physics. Miscellaneous Data. Information Theory. Probability and Statistics. Fourier Waveform Analysis. Maxwell's Equations. Mathematical Formulas. Mathematical Tables.

An Introduction to Junction Transistor Theory. R. D. Middlebrook. New York, John Wiley & Sons, Inc., 1957. 296 pp., illus., diagrs. $8.50.

The major purpose of this book is to provide a continuous development of basic junction transistor theory, starting from fundamental physical principles and closing with practical circuit representations. It presents a new practical equivalent circuit which represents the small-signal behavior of a junction transistor over its useful frequency range as an amplifier. Written from the viewpoint of the electrical engineer, the text presupposes only an elementary knowledge of electronics, physics, and mathematics. Dr. Middlebrook is a member of the Electrical Engineering Department, California Institute of Technology.

Basic Electrical Engineering; Circuits, Machines, Electronics, Control. A. E. Fitzgerald and David E. Higginbotham. 2nd Ed. New York, McGraw-Hill Book Company, Inc., 1957. 540 pp., illus., diagrs., tables. $6.50.

Stressing the scientific, analytical, and physical aspects of electrical engineering, this text presents a comprehensive introduction to circuit theory, machinery, industrial electronics and measurements, and feedback-control systems. New devices and concepts developed since 1945, such as recorders and controllers, phase-sensitive modulation and demodulation, control amplifiers, d.c. and a.c. control motors, and transfer-function and frequency-response analysis, are included in this edition.

The text is based on the experiences of teaching the subject at university level. Mr. Fitzgerald, formerly Professor of Electrical Engineering, M.I.T., is now with Jackson & Moreland, Inc., Engineers. Mr. Higginbotham is Associate Professor of Electrical Engineer, Tufts University.

EQUIPMENT, HYDRAULIC

Aircraft Hydraulics; Vol. 1, Hydraulic Systems. Edited by H. G. Conway. Published under the Authority of the Royal Aeronautical Society. London, Chapman & Hall Ltd., 1957. 146 pp., diagrs., tables. 35*s*.

The RAeS is sponsoring a series of textbooks designed both to fill the needs of the university student and starting technician in the field of aeronautics and to provide special study for the experienced engineer. This first publication is devoted to the broad principles of hydraulics as

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developed during the past 25 years and applied to aircraft equipment. The book consists of separate papers contributed by individual authors, each a specialist in his field. The editor is Director and Chief Engineer, Short Brothers and Harland Ltd., Belfast.

Contents: Fluids for Hydraulic Systems, A. E. Bingham. Hydraulic Theory: The Flow of Fluids, E. G. Collinson. Performance Problems of Pipes and Components, E. G. Collinson. Hydraulic Systems, S. M. Parker. Hydraulic Circuits, H. G. Conway. Installation and Operation: The Installation of an Aircraft Hydraulic System, A. Black. Installation and Operation: The Testing of Hydraulic Systems, A. Black.

INSTRUMENT FLYING

Instrument Flying. P. V. H. Weems and Charles A. Zweng. 6th Rev. Ed. Annapolis, Md., Weems System of Navigation; North Hollywood, Calif., Pan American Navigation Service, 1957. 298 pp., illus., diagrs. $6.00.

This latest edition of a standard text is directed toward private and commercial pilots and navigators rather than military personnel. Many recent innovations such as the Sperry Zero Reader, Gyrosyn compass, Collins integrated flight system, and radar for present-day landing systems are covered, and the text is supported by questions and answers on Civil Air Regulations, navigation, radio, and meteorology.

MACHINE ELEMENTS

Bearing Design and Application. Donald F. Wilcock and E. Richard Booser. New York, McGraw-Hill Book Company, Inc., 1957. 464 pp., illus., diagrs., tables. $12.50.

A practical guidebook for the machine designer in selecting and designing bearings, with emphasis on selection and calculation methods for integrating the bearing design, bearing material, and lubricant into a workable unit. It provides the reader with a comprehensive picture of the factors entering bearing design and of application problems in almost all types of industrial equipment: turbine, motor, automotive, appliance, and aircraft and military units.

Among the subjects covered are analysis of load capacity, speed, temperature, dimensional tolerance, and lubrication factors in selecting ball and roller bearings; combination of the latest digital computer analysis with bearing material and lubricant selection in hydrodynamic journal and thrust bearings; reciprocating bearing methods for automotive and diesel use; lubrication system designs; and systematic trouble-shooting techniques for analyzing and eliminating difficulties. Both authors are managers of divisions of the General Electric Company.

Mechanisms and Dynamics of Machinery. Hamilton H. Mabie and Fred W. Ocvirk. New York, John Wiley & Sons, Inc., 1957. 442 pp., illus., diagrs., tables. $8.50.

The material in this book has been taught to undergraduates of Cornell University for several years. The authors, Associate Professors of Mechanical Engineering, have made the text as brief as is consistent with a thorough presentation of the fundamentals of the subject.

Part 1, on Mechanisms, deals with spur gears; nonstandard spur gears; linkages; bevel, helical, and worm gearing; and computing mechanisms. It assumes as background a familiarity with physics and calculus on the part of the reader. *Part 2*, Dynamics of Machinery, covers the kinematics, force analysis, balance, and vibration of machines and presupposes a knowledge of statics and dynamics.

MATERIALS

Engineering Uses of Rubber. Edited by A. T. McPherson and Alexander Klemin. New York, Reinhold Publishing Corporation, 1956. 490 pp., illus., diagrs., tables. $12.50.

Unable to find adequate information on the use of rubber in aeronautical engineering problems, the late Dr. Klemin undertook the preparation of this book from the point of view of the engineer

outside the rubber industry. Four major areas are covered: the making of rubber goods, the properties and behavior of rubber, its applications in different industries, and the means of obtaining rubber products either by purchase on specification or by special construction. Contributions are from well-known rubber scientists and technologists, and the final preparation of the book has been under the direction of Mr. McPherson, Associate Director, National Bureau of Standards.

Contents: (1) Introduction, Ernst A. Hauser. (2) Making Rubber Products for Engineering Uses, E. G. Kimmich. (3) Compounding—The Art of Tailoring the Properties of Rubber to the Use, G. C. Maassen. (4) General Engineering Properties of Rubber, E. G. Kimmich. (5) The Design of Rubber Mountings, J. F. Downie Smith. (6) Deterioration of Rubber From Use and With Age, J. Crabtree and F. S. Malm. (7) Rubber in Civil Engineering, W. E. Scoville, Jr. (8) Rubber in Chemical Engineering, B. S. Garvey, Jr. (9) Rubber in Electrical Engineering, G. J. Crowdes. (10) Tires, R. H. Spelman. (11) Belt Conveyors, Paul D. Suloff. (12) Rubber in Automobiles, J. W. Marshall. (13) Rubber and Aviation, J. J. Allen, R. W. Wixom, and H. C. Chandler, Jr. (14) Specification and Inspection of Rubber Products, W. J. McCortney and W. J. Simpson. (15) Rubber Products for New or Special Purposes, Ellwood F. Riesing and Jack E. Gieck. (16) Molecular Structure and Mechanical Properties of Polymers. Name Index. Subject Index.

Analysis of Deformation: Vol. 1, Mathematical Theory; Vol. 2, Experiment and Applied Theory. London, Chapman & Hall, Ltd.; New York, The Macmillan Company. Vol. 1, 1954, 285 pp., diagrs., $12.75; Vol. 2, 1955, 365 pp., diagrs., $13.50.

The first volume in this series dealing with deformity of substances under applied loads formulates the mathematically linear theory for analyzing deformation and draws general inferences without solving the equations and boundary conditions for particular cases. Volume 2 presents the application of the theory in its "practical" aspect so that in some cases approximations have been made in the intuitive, engineering sense as required but always indicating the nature of the approximation when compared with the rigorous theory. Volume 3, previously annotated, deals with Fluidity. Most of the ideas presented in the series were evolved during the author's tenure of an Imperial Chemical Industries Research Fellowship in the University of London during the years 1945–1950.

Contents: Volume 1. (1) Displacement. (2) Stress. (3) Strain. (4) General Considerations on Stress and Strain. (5) Thermal Considerations. (6) Isotropic Elastic Substances. (7) Visco-Elastic Isotropic Substances. (8) Yield. (9) Elasto-Plastic Isotropic Substances. Appendix A, Vector Analysis. Appendix B, Scalar Analysis. Appendix C, Potential Theory and Related Theorems. References. Glossary. Author Index. Subject Index.

Volume 2. (1) One-Stress Definitions and Tests. (2) One-Stress Theoretical Considerations. (3) Homogeneous, Plane Two-Stress. (4) Homogeneous, Curvilinear Two-Stress. (5) Heterogeneous Two-Stress Equations for Solution. (6) Heterogeneous Two-Stress Experiments. (7) Two-Stress Theoretical Examples. (8) Three-Stress Equations for Solution. (9) Three-Stress Analyses. (10) Rubber Deformation and Its Theoretical Interpretation. (11) Couples Applied to Massive Bodies. (12) Shearing Thin, Plane Laminae. Appendix A, Vector Analysis. Appendix B, Complex Variable. Appendix C, Finite Differences. Appendix D, Fourier Series. References. Glossary. Author Index. Subject Index.

Fibres, Plastics, and Rubbers; A Handbook of Common Polymers. W. J. Roff. London, Butterworths Scientific Publications; New York, Academic Press, Inc., 1956. 400 pp., diagrs., tables. $10.

A compilation of extensive chemical, physical, and general information on common high polymers. Arranged for ready reference and intended primarily for those engaged in industrial research and development, the work serves also as a practical introduction to the constitution, properties, identification, and utilization of these materials. The author, a member of the British Cotton Industry Research Association, has gathered the material from published literature, unpublished private works, and from original measurements made at the Shirley Institute.

MATHEMATICS

Statistical Analysis of Stationary Time Series. Ulf Grenander and Murray Rosenblatt. New York, John Wiley & Sons, 1957. 299 pp., tables. $11.

The dual purpose of this book is to acquaint the theoretical statistician with an approach to time series that is essentially different from most of the techniques used by time series analysts in the past and to present a unified treatment of methods that are being used increasingly in the physical sciences and technology. The analyses are accompanied by rigorous proofs, requiring on the part of the reader a knowledge of statistics and basic probability theory equivalent to that contained in H. Cramér's *Mathematical Methods of Statistics*. The material presented is bounded by the following limitations: Almost all examples discussed in the text are chosen from the physical sciences; only processes with stationary residuals are studied; there is very little discussion of vector processes; and only large sample methods are considered. The authors are, respectively, Docent, University of Stockholm, and Associate Professor of Mathematics, Indiana University.

Contents: (1) Stationary Stochastic Process and Their Representations. (2) Statistical Questions When the Spectrum Is Known (Least Squares Theory). (3) Statistical Analysis of Parametric Models. (4) Estimation of the Spectrum. (5) Applications. (6) Distribution of Spectral Estimates. (7) Problems in Linear Estimation. (8) Assorted Problems. Problems. Appendix on Complex Variable Theory. Bibliography. Index.

METEOROLOGY

Physics in Meteorology. A. C. Best. London, Sir Isaac Pitman and Sons, Ltd.; New York, Pitman Publishing Corporation, 1957. 159 pp., diagrs., tables. $3.75.

A brief account of selected aspects of meteorology in which the science of the atmosphere is shown to be a branch of physics and consequently explainable in terms of the laws of the physical laboratory. The author is Deputy Director of the British Meteorological Office and has served in the research branches and on the operational side of the Office at home and overseas.

Contents: (1) Meteorological Instruments. (2) The Microphysics of Cloud, Precipitation and Fog. (3) Radiation. (4) Atmospheric Electricity. (5) Wind.

MISSILES

The Handbook of Rockets and Guided Missiles. Norman J. Bowman. Chicago, Perastadion Press, 1957. 328 pp., diagrs. $6.50.

The purpose of this handbook is twofold: to serve as a reference book to rockets and missiles, both historical and modern, and to furnish a review of the present status of missile development as it may be inferred from the existing unclassified literature. Its scope is broader than the title indicates in that data are supplied not only for rockets, rocket engines, and guided missiles but also for unmanned guided aircraft, manned rocket planes, and jet engines employed in missiles. The major portion of this book is devoted to a table of data in which missiles, rockets, planes, and engines are listed in alphabetical order under their common names. There is comprehensive referencing to other names and military designations and to published literature. Following this table are over 1,200 citations of the literature and 170 drawings of various missile and rocket configurations known to be in existence as of 1956. Dr. Bowman is on the editorial staff of the *Journal of*

Aeronautical Engineers

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Design and development of production test and field test equipment where specific objectives and general requirements are known in the electrical and mechanical engineering fields. Must have experience on design or development of electromechanical instruments.

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Responsible for establishing overall data reduction procedures. Direct the activities in specifying and procuring all components of standard automatic digital and analog data handling and processing equipment. Responsible for design or procurement of special data processing equipment.

FUNCTIONAL ENGINEERS—MISSILE SYSTEMS
Develop inertial guidance systems including gyro, accelerometers, integrators, servo systems and computers. Analyze functional problems arising during development and evaluation of said system.

ELECTRO-MECHANICAL ENGINEER
Conduct investigation on special electromagnetic and electromechanical devices including evaluation and/or design of transducers, servo systems and related devices.

GROUND EQUIPMENT ENGINEER
Plans and performs engineering studies, basic electrical and mechanical design, development and evaluation of production test and field test equipment where specific objectives and general requirements are known. Must be familiar with electromechanical instrumentation.

TRANSISTOR CIRCUIT ENGINEER
Pulse application of high speed transistors used in airborne digital computers. Circuit design applications requiring knowledge of latest transistors such as tetroids and superficial barriers.

DIGITAL COMPUTER ENGINEER
Basic research and development including logical design, dynamic analysis, component development, hardware and packaging, system and component reliability, and laboratory and field evaluation of complex computers for fire control and guidance systems.

FIELD EVALUATION ENGINEER
Perform overall planning functions for field evaluation of missile guidance systems. Direct activities in scheduling the field operations. Liaison with field test site agencies and formulating overall operating procedures at test site on missile project.

PROJECT ENGINEER—AIRBORNE EQUIPMENT
Project engineering of computers, pro and anti submarine fire control equipment, airborne navigation plotting equipment and similar equipment. Preparation and proposals on equipment of such types.

PRODUCT ENGINEER
Initiate, compile and maintain design standards on electrical, electronic and mechanical design subjects pertinent to fire control equipment and inertial guidance components. Must have considerable responsible experience on product design standards covering areas indicated in job studies.

DEVELOPMENT ENGINEER—RADAR
Research and development engineering of new radar, navigation and guidance systems. Responsibility of theoretical and laboratory phases of research and development of radio frequencies and pulse circuitry portions of such systems. Experience in modulator, intermediate frequency amplifier, indicator, synchronizer, or R.F. component design is applicable.

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ENVIRONMENTAL TEST ENGINEER
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ENVIRONMENTAL ENGINEER
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Contents: (1) Introduction. (2) Ground Launched Missiles. (3) Air Launched Missiles. (4) Foreign Missile Progress. (5) Rocket Planes and Auxiliary Power Units. (6) Jet Engines for Missile Applications. (7) Upper Atmosphere Research Tools. (8) The Artificial Satellite. (9) The Intercontinental Missile and the Future. Tabulated Data on Rockets and Guided Missiles. References. Drawings of Rockets and Missiles.

NUCLEAR ENERGY

Radiation Safety and Major Activities in the Atomic Energy Programs, July–December 1956. U.S. Atomic Energy Commission. Washington, Superintendent of Documents, January, 1957. 396 pp., illus., diagrs., tables. $1.25.

Part 1 of the report covers the following areas of activities: international and domestic industrial programs, raw materials, military application, reactor development, education and training, physical research, biology and medicine, security, community operations, organization and personnel, and patents.

Part 2 deals with the following aspects of radiation safety: radiation safeguards for licensed activities, safety factors in reactor design and operation, radioactive wastes, radiation protection in Commission activities, research programs on radiation effects and treatments.

The Appendixes include such data as membership of the different committees of the AEC; major research and development installations of the Commission; regulations of the AEC; patents; licenses applied for and issued; the Commission's Financial Report for Fiscal Year 1956; and a Table of Nuclear Reactors, which gives a listing by designation, location, builder, and type, of all facilities, built, building, or planned in the United States as of December 31, 1956, which are capable of sustaining a nuclear chain reaction.

POWER PLANTS

1956 Aircraft Spark Plug and Ignition Conference Report, Toledo, Ohio, October 2–4, 1956. Sponsored by Champion Spark Plug Company, Toledo, Ohio, 1956. 111 pp., illus., diagrs., 5 folded charts.

Discussion of spark plug phenomena and problems encountered by operators of military and commercial aircraft, with some reference to helicopter operation.

Contents: (1) Spark Plug Service Experience. (2) Spark Plug Fouling. (3) Effects of Fuel and Lubricants on Spark Plugs. (4) Recondition, Test and Inspection of Spark Plugs. (5) Research and Development. (6) Ignition Analyzers. (7) Magnetos—Harness—Leads. (8) Jet Ignition. Appendix I, Review of Champion Aircraft Spark Plug Manufacturing Improvements. Appendix II, Résumé of Research and Development Activities. Index.

PRODUCTION

Cost-Quantity Relationships in the Airframe Industry. Harold Asher. (U.S. Air Force Project Rand, Report No. R-291.) Santa Monica, Calif., The RAND Corporation, July 1, 1956. 191 pp., diagrs., tables.

This report is a study of the technique employed to estimate the cost of producing air frames. It indicates that the conventional progress curve, which is linear on logarithmic grids, is not an accurate description of the relationship between unit cost and cumulative output beyond certain limits in the number of units produced. Applied to large production quantities, the "linear" curve tends to lead to cost estimates that are too low. If a large percentage of error is allowable in specific application, then the linear curve may be adequate. If the application permits only a relatively small error, a convex curve of the type developed in this report is probably more appropriate. In addition to estimating contract prices, the principle of the progress curve is frequently applied to aircraft equipment, as well as to other

types of products, whether for military or civilian consumption.

Contents: (1) Introduction. (2) Development of the Theory of Progress Curves. (3) Progress-Curve Data. (4) The Linear Hypothesis. (5) The Direct-Labor Progress Curve. (6) The Production-Cost Progress Curve and Total Airframe Cost. (7) Conclusion.

QUALITY CONTROL

Quality Control for Plastics Engineers. Edited by Lawrence M. Debing. Sponsored by the Society of Plastics Engineers, Inc. New York, Reinhold Publishing Corporation, 1957. 142 pp., diagrs., tables. $4.95.

This book introduces to engineers and manufacturers the subject of statistical quality control as a technique for maintaining the highest quality levels in the production of plastic products. The methods by which this is accomplished are described in contributions by members of the Committee on Quality Control, Society of Plastics Engineers.

Mr. Debing is General Superintendent, Plant Laboratories, Monsanto Chemical Company.

THERMODYNAMICS

Proceedings of the Symposium on "High Temperature—A Tool for the Future"; Held at Berkeley, Calif., June 25–27, 1956. Sponsored by Stanford Research Institute and University of California. Menlo Park, Calif., Stanford Research Institute, 1956. 218 pp., illus., diagrs., tables. $5.00.

Contents: Methods for Reaching High Temperatures—Images of Very High Temperature Sources: Images of Very High Temperature Sources, Joseph Farber. The Carbon Arc Image Furnace, T. P. Davis. Large-Area High-Temperature Sources, Joseph M. McGreevy. Extremely High Gas Temperatures by Means of Short Time Electrical Discharges, Heinz Fischer. *Electrical Methods for Obtaining High Temperatures:* Electrical Methods of Reaching High Temperatures, H. G. MacPherson. The Probable Role of Induction Heating, Frank T. Chesnut. The Behavior of Matter at High Temperatures, Wolfgang Finkelnburg. Resistance Methods of Heating, Gordon Finlay. *Chemical and Nuclear Methods of Obtaining High Temperatures:* Chemical Processes as Methods of Achieving High Temperatures, David Altman. Production of High Temperatures by Shock Waves, George E. Duvall and Milton C. Kells. The Production of High Temperatures by Chemical Means and Particularly by the Combustion of Metals, A. V. Grosse. High Temperature Nuclear Heat Sources, Richard H. Graham.

Materials for Containing High Temperatures—Structures and Properties: Strength of Alloys at Elevated Temperatures, John C. Fisher. Ductile Ceramics, Earl Parker. Substances with High Melting Temperatures, J. T. Norton. Refractory Coatings, Samuel W. Bradstreet. *Equilibrium Considerations for Interaction of High Temperature Materials With Their Environment:* Equilibrium Considerations for Interaction of High Temperature Materials with Their Environment, John L. Margrave. The Correlation of Interrelated Thermodynamic and Thermostatic Measurements to Yield Equilibrium Data, R. K. Edwards. Salt-Metal Liquid-Phase Equilibria, M. A. Bredig. Some Considerations for the Selection of Materials for Containing High Temperatures, Tibor Laszlo. *Kinetic Considerations for Interaction of High Temperature Materials with Their Environment:* Reaction of Metals with Their Environs at High Temperatures, Daniel D. Cubicciotti, Jr. Corrosion of Refractories by Liquid Melts, William D. Kingery. Some Kinetic Considerations About Fused Salts, E. R. Van Artsdalen. Behavior of High Temperature Materials in High Radiation Density Environments, Clifford Weber.

Keynote Address: Aerodynamic Heating—The Temperature Barrier in Aeronautics, Theodore von Kármán.

(*Continued on page 229*)

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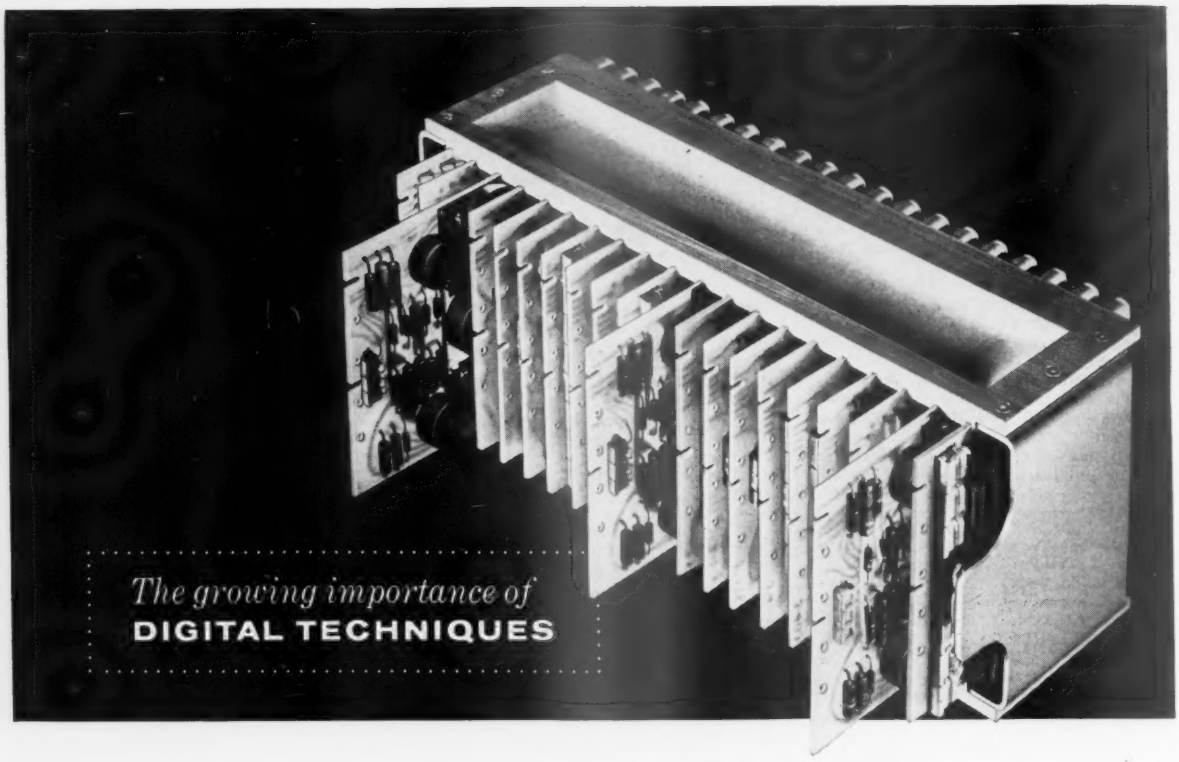

As recently as ten years ago it was just becoming evident that digital techniques in electronics were destined to create a new and rapidly growing field. Today, incorporated in electronic computers and other equipment, they constitute one of the most significant developments in scientific computation, in electronic data processing for business and industry, and in electronic control systems for the military. In the near future they are expected to become a major new factor in industrial process control systems.

The digital computer for scientific computation is becoming commonplace in research and development laboratories. Such machines range from small specialized units costing a few thousand dollars, to large general purpose computers costing over a million dollars. One of these large computers is a part of the Ramo-Wooldridge Computing Center, and a second such unit will be installed the latter part of this year. The digital computer has not only lightened the computation load for scientists and engineers, but has made possible many calculations which previously were impracticable. Such computers have played a major role in the modern systems engineering approach to complex problems.

Electronic data processing for business and industry is now well under way, based on earlier developments in electronic computers. Data processors have much in common with computers, including the utilization of digital techniques. In this field, teams of Ramo-Wooldridge specialists are providing consulting services to a variety of clients on the application of data processing equipment to their problems.

The use of digital techniques in military control systems is an accomplished fact. Modern interceptor aircraft, for example, use digital fire control systems. A number of Ramo-Wooldridge scientists and engineers have pioneered in this field, and the photograph above shows a part of an R-W-developed airborne digital computer.

These, then, are some of the aspects of the rapid growth which is taking place in the field of digital techniques. Scientists and engineers with experience in this field are invited to explore openings at The Ramo-Wooldridge Corporation in:

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This section is for the use of individual members of the Institute seeking new connections and organizations offering employment to Aeronautical specialists. Any member or organization may have requirements listed without charge by writing to the Secretary of the Institute.

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Assistant or Associate Professor—Position in aeronautical engineering open as of July 1 or September 15, 1957. Applicant should be qualified to teach graduate and/or undergraduate work. Joint research and teaching appointment available. Enclose an outline of education, experience, and references in initial reply. Apply to Chairman, Department of Aeronautical Engineering, Iowa State College, Ames, Iowa.

Assistant Professor or Instructor in Aeronautical Engineering—Positions are open for teaching and research in several subjects. An advanced degree is required for the rank of Assistant Professor. Send résumé of education, experience, and field of interest to Chairman, Aero. Engrg. Dept., University of Kansas, Lawrence, Kan.

Instructor—To teach aeronautical engineering. Ample consulting opportunities. Salary and rank commensurate with training and experience. Nine-month school year. Reply to Chairman, Department of Engineering, San Diego State College, San Diego 15, Calif.

Engineers—Princeton University offers unique positions for qualified engineers in challenging scientific research. Under sponsorship of the University, private industry, and the Government, the Aeronautical Engineering Department is engaged in significant and timely research in jet propulsion at the James Forrestal Research Center, 3 miles from the University campus. Key positions are presently available for engineers with experience in rocket technology and/or propellant evaluation to serve as project engineers in charge of major research. The positions are academic appointments with University privileges, participation in graduate courses, and 1-month annual vacation. Résumés or requests for further information may be sent to Silas Spengler, 123 Pyne Administration Building, Princeton University, Princeton, N.J.

Aeronautical Engineers—Creative and challenging assignments now available with the new

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Engineers—The Air Technical Intelligence Center has reported immediate openings for petroleum fuels and lubricants engineers at salaries to $8,990 per annum. The positions stress the ability to evaluate petroleum refining processes; to construct flow charts and material balances. The applicant must be familiar with the chemistry of petroleum processes, as well as the construction and design of refinery facilities. Those with knowledge of foreign languages will be given additional consideration. Applications should be addressed to Commander, Air Technical Intelligence Center, Attn.: AFOIN-4X2b, Wright-Patterson Air Force Base, Ohio.

Aeronautical and Mechanical Engineers and Electronic Scientists—The Flight Test Division of the Naval Air Test Center has openings for aeronautical and mechanical engineers at Grades GS-5 to GS-12, salaries from $4,480 to $7,570 per annum, and electronic scientists at grades GS-5 to GS-11, salaries from $4,480 to $7,035 per annum. The Flight Test Division is engaged in the evaluation of new Navy fighter aircraft, high-speed flying boats, and all types of helicopters. Work includes performance, stability and control, carrier suitability, and hydrodynamics. The incorporation of automatic data-handling systems and telemetering techniques has increased the divisional needs for electronic engineers. The work is closely associated with the aircraft development work of the majority of the major aircraft manufacturers of the country. Visits to major air installations throughout the country are a routine part of this engineering work, and tests are conducted regularly aboard the Navy's newest aircraft carriers. Opportunity exists for both the experienced engineers and the recent graduates. In several positions, piloting background is desirable. Send a résumé to the Chief Engineer, Flight Test Division, Naval Air Test Center, Patuxent River, Md.

Engineers—The Army Transportation Research and Engineering Command has openings for aeronautical research and development engineers for supervision and management of programs in the fields of STOL/VTOL aircraft and helicopters. Specialty fields include aerodynamics, rotary wing, stability and control, structures, power plants, and propellers. These positions include GS-11 through GS-14 grades, with starting salaries ranging from $7,035 per annum to $11,395. Additional information may be requested by writing to the Commanding Officer, Transportation Research and Engineering Command, Fort Eustis, Va.; or applications may be submitted on Standard Form 57, addressed to the Civilian Personnel Division, Fort Eustis, Va.

Research Assistants and Teaching Assistants—Opportunities for full- or part-time employment on Government contracts in mechanics with emphasis on elasticity, vibrations, and electronic instrumentation. Some applied mathematics or electromechanical experience desirable. Part-time teaching assistantships available for undergraduate instruction. Graduate study commen-

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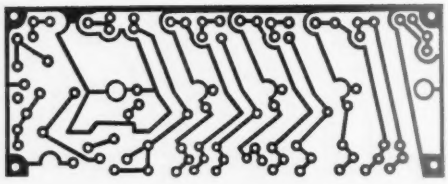

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803. Engineer—Canadian; 15 years' airline and manufacturing experience; 8 years at chief engineer level. Registered professional engineer; approved by Department of Transport; broad administrative and product development background. Interested in long-range opportunity for responsible work.

802. Instructor—B.S. (Eng. Physics), M.Sc., and Ph.D. (Aero.). Four years' experience in teaching of junior, senior, and graduate courses in aerodynamics. Capable of teaching high-level courses in compressible flow, stability and control, viscous flow, and potential flow. Interested in obtaining position at the Professor or Associate Professor level in an accredited aeronautical engineering department with some opportunity for research.

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Processes Occurring at High Temperatures—Gas State Reactions: Theoretical Information Obtainable from Reaction Rate Studies Over a Wide Temperature Range, Harold S. Johnston. Shock-Tube Studies for the Determination of Physico-Chemical Parameters, S. S. Penner and V. Vali. *Condensed State Reactions:* Condensed State Reactions, S. S. Kistler. Some Condensed State Reactions in the High Temperature Field, Harold Feder. Chemistry at High Temperature and High Pressure, H. T. Hall. Condensed Phase Reactions, C. Law McCabe. *Interactions Between Gases and Condensed Phases:* Interactions Between Gases and Condensed Phases, Paul W. Gilles. Vapor Deposition of High-Temperature Coatings, I. E. Campbell. Applications of Mass Spectroscopy to High-Temperature Vaporization Studies, Richard F. Porter. The Present Status of Electromagnetic Levitation as a High Temperature Research Tool, J. C. R. Kelly. *Temperature—Its Definition and Measurement,* Carsten Steffens. Questions to the Panelists and Their Answers.

VIBRATION

Vibration Analysis Tables. R. E. D. Bishop and D. C. Johnson. Cambridge, England, At the University Press; New York, Cambridge University Press, 1956. 59 pp., tables. $2.00.

A collection of 20 tables extracted from the authors' forthcoming *Mechanics of Vibration.* A few appeared previously in the *Royal Aeronautical Society Journal* and the *IME Proceedings.*

Contents: Receptance Functions of Torsional Systems. Receptances of Composite Systems. Frequency Equations of Composite Systems. Lateral Vibration of Taut Uniform Strings. Torsional Vibration of Uniform Circular Shafts. Longitudinal Vibration of Uniform Bars. Flexural Vibration of Uniform Bars (Receptances, Characteristic Functions and Other Data, Flexibilities). Bibliography.

WIND TUNNELS

The Use of Rheoelectrical Analogies in Aerodynamics. L. C. Malavard. (AGARDograph No. 18.) Paris, NATO, AGARD; Washington, Distributed in the United States by NACA, August, 1956. 175 pp., illus., diagrs.

The rheoelectric analogy method is based on the identity between the equations which govern certain fluid flows and those for the distribution of electric potential in a continuous conducting medium (electric tank, conducting paper, etc.). After a review of the principle of this method, the study describes the equipment and experimental techniques used in model construction, in the physical realization of the given problem data, in the exploration of the potential fields, and in carrying out the necessary adjustments and measurements. Next the different aerodynamic applications are examined: representations of plane flows, studies of airfoil sections and turbine blade lattices, practical accomplishment of conformal mappings, and studies of axially symmetric and three-dimensional flows. Detailed descriptions are given of the analog methods and setups used for the solution of lifting line, propeller, lifting surface, and compressible flow problems. The author is Professor, Chaire d'Aviation, Faculté des Sciences de Paris.

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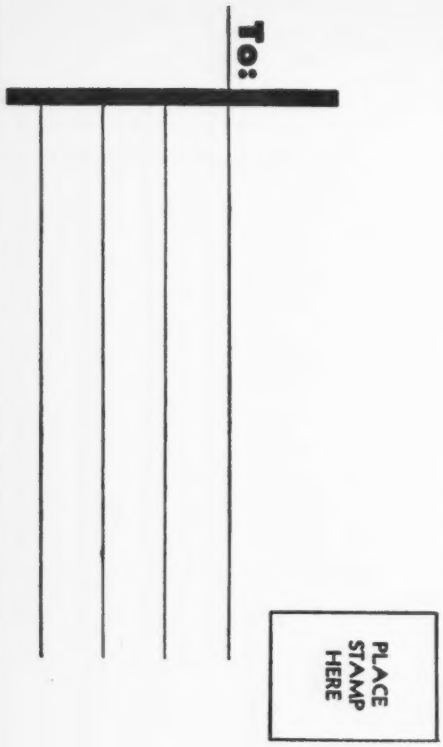

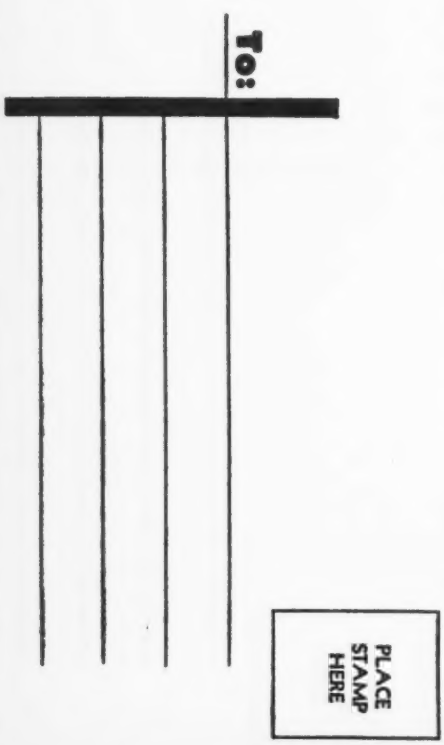

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Miniature Gear Head Motor. 115 V.D.C. ± 5 V.D.C.; output speed is 12.5 r.p.m. ± 25 per cent. Current drain is 100 MA. *Western Gear Corp.*, Electro Products Div., Lynwood, Calif.

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Model 4920-AN Hollow Coil Proximity Pickup. For counting small metal parts such as screws, nuts, washers, and bolts. *Electro Products Laboratories, Inc.*, 4500 Ravenswood Ave., Chicago 40.

Uses of Microfilm for Engineering Department Drawings & Records. 36-page brochure "New Horizons With Microfilm." *Filmsort Div.*, Dexter Folder Co., 50 S. Pearl St., Pearl River, N.Y.

Dimpling Machine for High-Temperature Alloys. Model C-125 handles 17-7 PH and 15-7 Mo. stainless steels, as well as vanadium and manganese alloys of titanium. *The Lemert Engineering Co., Inc.*, 201 E. Jefferson St., Plymouth, Ind.

RESEARCH & TEST EQUIPMENT

1/2-In. Aluminum-Alloy Check Valve. Data sheet describes this new MS-approved valve. *Aircraft Products Co., Tactair Valve Div.*, 300 Church Rd., Bridgeport, Pa.

High Input Impedance Amplifier. Type 104 is useful for maintaining low-frequency response and signal level of piezoelectric accelerometers, pressure pickups, and similar transducers. *Atlantic Research Corp.*, 901 N. Columbus St., Alexandria, Va.

Series 8000 Electronic Multipoint Recorder. For permanent recording of up to 16 points on one chart. *Barber-Colman Co.*, Wheelco Instruments Div., Rockford, Ill.

Electronic Test Instruments. 4-page catalog describes expanded scale voltmeters and frequency meters, synchro tester, oscillators, power supplies, etc. *Beckman Instruments, Inc.*, Shasta Div., P.O. Box 296, Sta. A, Richmond, Calif.

Chilling Machine for Wire Testing. Model U-70-6 has temperature adjustment from −10° to −80°F. and a thermal capacity of 200 B.t.u./hour at −70°F. *Cincinnati Sub-Zero Products*, Reading Rd. at Paddock, Cincinnati 29.

"Goniometer" Instrument Angle Measuring Fixture. Provides an accurate means of measuring or adjusting the shaft angle of precision components. *Electro-Mec Laboratory, Inc.*, 47–51 33rd St., Long Island City 1, N.Y.

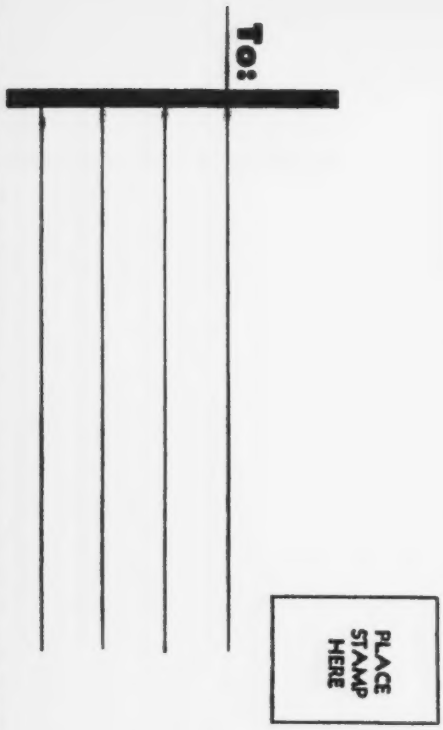
Radar Moving Target Simulator System. Generates the display of up to six individual moving targets on any standard radar indicator. *Fairchild Controls Corp.*, Electronics Div., Syosset, N.Y.

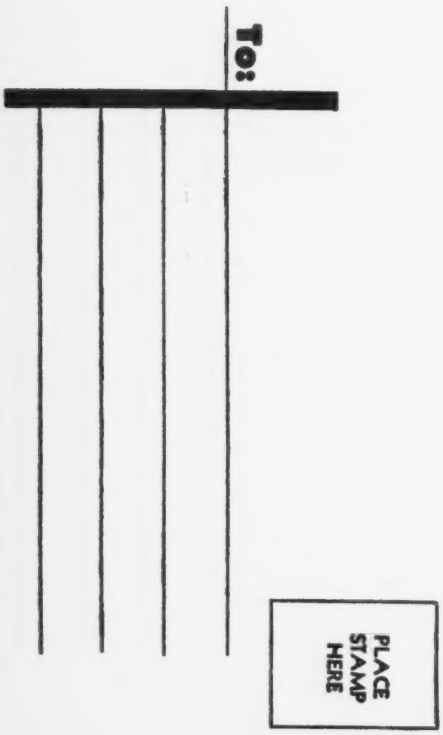
Model CPD-3 Infrared Radiation Source. Provides black body infrared radiation over a broad range of temperatures. *Haller, Raymond & Brown, Inc.*, State College, Pa.

Model 400A Digital Printer. Features rapid print-out, parallel entry, and up to twelve digit printing; uses no stepping switches. *Measurements Corp.*, 5528 Vineland Ave., N. Hollywood, Calif.

"Optron" Vibration Measuring Instrument. An optical device for measuring displacement and vibration; works on any material regardless of size, shape, or composition. *Optron Corp.*, 3526 State St., Santa Barbara, Calif.

RT-500 Transmitter-Receiver Performance Test Set. This preflight unit analyzes weaknesses and predicts possible "in flight" failures of aircraft electronic equipment. *Trad Electronic Corp.*, Asbury Park, N.J.





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